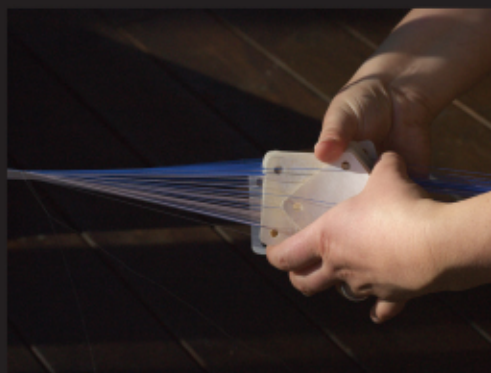


Ancient Textiles Modern Science



edited by

Heather Hopkins

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Ancient Textiles, Modern Science

Re-creating Techniques through Experiment

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Re-creating Techniques through Experiment

Proceedings of the First and Second European Textile Forum
2009 and 2010

edited by

Heather Hopkins

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Front cover: Top left: Tablet weaving in progress. Photo: Katrin Kania

Top right: Dyeing wool with madder. Photo: Heather Hopkins

Bottom left: Mordanting wool with alum. Photo: Heather Hopkins

Bottom right: Reconstruction of lime bast shoes. Photo: Anne Reichert

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Introduction

The number of people involved in ancient technology is growing by the day. Some of them are archaeologists, others are teachers, students, artists or crafts people to name just a few. Ancient technology attracts many kinds of people because it bridges between our hands and the hands of our ancestors – and with that we have one of the most direct links with the past we can imagine.

At the yearly EXAR conference on experimental archaeology, many people meet and many ideas cross the table. It was in October 2008, that the idea was first mentioned of organising a get-together for anybody interested in textiles using a hands-on and archaeological approach. True, there are conferences like the famous NESAT textile conference but why not use a workshop or forum approach?

In HOME Eindhoven, now Eindhoven Museum, an archaeological open-air museum founded in 1982, it has been done: we brought a number of people together who all were interested and experienced in a specific craft – for one week they immersed in doing practical work during the day and listening to more formal presentations in the evening. For the museum, it was a unique experience showing the public something you do not see every day. For the participants, it was better than a conference where usually there is too little time to sit together and discuss technicalities and approaches in more detail.

Using the HOME Eindhoven workshops as inspiration, Kania and Ringenberg have developed an approach which fits very well with the textile people they have in mind. They combine the archaeological view with experience in textile working; and through this diverse network got a group together large enough to start a ‘buzz’ on Day One of the first Forum in Eindhoven. I was happy to have been of some small assistance and to see the ball roll on.

The second Forum built on the first, and thanks to the contacts and perseverance of the two leading colleagues, that too was a success. The Archeoparc at Val Senales, not far from where Ötzi was found, proved to be a very well chosen follow-up location after HOME Eindhoven.

The international character is one of the strengths of the Textile Forum. Often we find one or two colleagues nearby, but in this relatively small world of textile crafts and archaeology, one needs to be able to rely on far friends – and the Forum is the perfect place to sit down and work together. The strength is in its simplicity of combining networking, research and a textile market into one single happening.

Another strength is that the forum is catering for a variety of people, bringing together specialisms which otherwise would never be so close to one another. Archaeology is not only science, and textile is not only craft. This cross-fertilisation has led to many interesting new leads, most of them not explored yet to the full.

The Textile Forum's first two years have been very productive and brought people together in a very pleasant way. The results of the two Forums – these proceedings – witness of both a serious and fruitful approach to textile craft and archaeology as well as of a series of collegial friendships which would not have existed otherwise.

The Textile Forum is not an official association, foundation, platform or similar. That is both a strength and a weakness. With the publication of these present proceedings, an important step is made to make the Textile Forum and its results better known to other textile enthusiasts.

Roeland Paardekooper MA PhD
EXARC Director
The Netherlands

A Conference from the Craftsperson's Perspective: introduction to the European Textile Forum

Sabine Ringenberg and Katrin Kania

As far as conferences go, the European Textile Forum is a quite unusual one. Concentrating on the aspects of craftspersonship and crafting, it caters to the very special and individual needs of those persons working with historical textile techniques. This includes an uncommon schedule of papers in the evening and the daylight hours reserved for archaeological experiments, workshops or simply exchange between the participants and hands-on discussion on and about their current textile projects.

With a full week running time, the Textile Forum is long enough for a larger experiment like the Spinning Experiment undertaken in 2009, and long enough for the participants to learn from each other and establish a good contact for further networking. This paper explains the reasons behind the Forum – and the possibilities of such a unique conference concept.

While textile in historical times was undoubtedly the most important means to show off wealth and taste, witnessed by pictures, texts, inventories and surviving textile works, the occupation with textile crafts in modern times has gained a somewhat demeaning reputation. Textile works are often seen as an undemanding pastime for frustrated housewives and the like. This view of textile crafts as something low in both status and material worth is further advanced by today's very cheap mass-produced textiles and clothing – but also by a phenomenon regarding historical techniques, where badly made products using wrong materials and much simplified historical techniques can be found. At 'medieval markets' and similar fairs, textile wares manufactured with historical techniques, such as tablet-woven bands, are quite frequently offered for little more than the cost of their materials, showing how little value is placed today on the time and knowledge necessary for their manufacture.

In direct opposition to this modern view of ancient textile crafts stand the fine, exacting textile objects from medieval times that still survive today. For making objects

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like these, three things are needed: a very high level of skill, expensive materials, and massive amounts of time. Due to this, most of the techniques demand a very well organised division of labour, mostly among many specialists of one social or economical group. To produce a single simple textile from a basic material such as wool or flax takes many steps of work, starting with sourcing the suitable raw fibre materials and ending with finishing tasks such as fulling and shearing or smoothing.

This multitude of steps until a final, finished object is achieved is something that textile work has in common with other crafts like pottery work or blacksmithing. However, there is a distinct difference in how these crafts are perceived today: while nobody would talk about smelting steel as any basic blacksmith's ordinary task to provide the workshop with the iron or steel needed, the preparation of fibres (both wool and flax), the production of spun yarns and weaving these yarns into cloth are often only seen as an aside to a normal woman's housework. For textile crafts, yarns are the basis for other work just as smelted steel is the basis for metalwork. And just like in other crafts, a division of labour for the different steps in manufacture is highly probable, at least for a professional or semi-professional workshop.

Division of labour may not be traceable in every instance, but a quick survey of surviving textiles shows that they could not have been all 'home-made' by non-professionals. On the contrary, textile production of high-quality items was an important factor of medieval economics (Cipolla 1993). Weaver's workshops as well as embroidery workshops in nuns' convents and monasteries are well-known from archaeological evidence and records (*e.g.* Windler and Rast-Eicher 1999/2000; Hamburger *et al.* 2007; Staniland 1991). A division of labour and specialisation is always connected to infrastructure: the specialists have to be supplied with tools, materials and also the necessities of daily life such as food and fuel. Textile work is time-consuming – many modern attempts at recreating historical textiles show this. Even if we have no way to reconstruct exactly the time needed in historical context by the appropriate professionals, the immensely fine work must have taken an appropriate amount of time – time that was not available for the worker to grow crops or tend to animals. The professionals in textile production must therefore have received enough wages for their work to sustain themselves. But not all trade and infrastructure regarding textiles will be possibly traceable from our time. Though spinning and weaving for the basic needs of a household or farm were probably common and basic knowledge – this does not imply that every household did all of its own textile work, or that every person was similarly skilled and enthusiastic regarding these tasks. The concept of being completely self-sustaining as an ideal situation is a rather modern one and not a reality we can expect to find in our history: even for the lower quality textiles produced as 'utility textiles' such as rough fabrics to cover, transport or package other goods in a home or farmstead, an informal barter of homemade textiles against other homemade goods or services can be easily imagined, as part of social and economical interaction to mutual benefit within a small community.

Historical textile crafts today

Today's textile production using historical tools and methods still follows the parameters of the ancient technical requirements: tools need to be made, raw materials have to be sourced, specialists must be found and, last but not least, a lot of time will have to be spent on the actual work. Since textile crafts in our modern world are often underestimated in regard to the craft skills, resources and qualified labour needed, the market for historical textile crafters is very small. So historical textile techniques used in a modern context are more or less a one-woman-show (or, very rarely, a one-man-show). Most of the persons working with historical textile crafts do it for their own enjoyment and as a private hobby; a few offer their services professionally and have an unrelated part-time or full-time job to support themselves; and only a very small number can manage to survive with working their textile crafts only.

The small demand for paid services in historical textiles leads to a very small number of professional, high-level crafters that usually have no large income and live scattered across Europe, with very limited possibilities to exchange knowledge. As a result, working in historical textile crafts can be a very lonely affair. Often, these crafters also have limited possibilities to stay up-to-date regarding current research from textile conservation or textile archaeology. The small number of these specialised crafters and their scant or non-existent connections to researchers have another negative side-effect: research projects regarding textile techniques cannot always find working textile specialists who could help with their knowledge and experience – a situation that is both unfortunate for the researchers who may need to re-invent the wheel or cope with problems that could be easily avoided through help of an experienced craftsperson, and for the crafters who are not getting an opportunity to work with researchers – which would not only mean recognition and payment for their expertise, but also a possibility to pass on their knowledge to more persons.

The isolation of crafters from textile researchers as well as from other crafters usually leads to each person having to do things largely on his or her own. Having to do the work for every step of the process oneself, or at least gaining the knowledge and researching to find the appropriate semi-finished products for a project, will certainly lead to the crafter learning much about processes of the trade and appreciating the knowledge and experience that went into historical textiles. This intensive occupation with the whole process may seem like a good thing at first glance. However, it also brings a certain danger of getting stuck in a process or making unnecessary mistakes and blunders. The knowledge and experience of the many processes necessary to go, for example, from a sheep's fleece to a finished dyed piece of cloth, are not all easily available or quickly gathered, especially not if the single steps demand a very high skill of the worker. Having to do everything by oneself also leads to individual crafters reinventing the wheel over and over and over again, and needing to learn a larger number of craft skills than might be beneficial to their primary work. It would not occur to a normal blacksmith to smelt all his or her own iron for everyday work, or to a normal restaurant chef to raise all his or her own meat animals and grow his or her own crops, yet it seems to be a popular assumption that a professional tailor working with historical patterns should also weave his or her own fabrics, a dyer grow his or her own dye plants, or a weaver spin his or

her own yarns. While such a large skill range at adequately high levels of craft skill for professional work can be found in some crafters, and while having full control over all the processes right from the start to the finished piece can be a wonderful thing and might be necessary in some cases, it should not be expected of a single craftsperson to have, at a professional level, all the skills for all the steps in the long process from fibre plant or animal to a finished piece of clothing.

Isolation of individual crafters means they will not have access to the expertise or services of other crafters specialising in tasks that would complement the primary skill of the craftsperson in question. For many historical textile works, it is a huge problem to find industrially produced semi-finished goods like yarns spun similarly to historical yarns. It thus becomes necessary for a high-quality, highly accurate reconstruction to source fibres and yarns somewhere else. The small quantities needed for a single reconstruction and the usually very small budget available rule out a special order from a spinning mill in most cases. Even finding tools needed for specific processes, or getting them made, can be a difficult task. These problems inevitably lead to textile crafters 'doing it themselves', and on their own – and therefore needing to expand their knowledge and skills. This is also harder to do in isolation than with the support and feedback of professional colleagues who may already have done their re-invention of that specific wheel, or have found a source for the tools and materials needed.

Communication between craftspersons and researchers

In addition to all these difficulties in the actual producing of textiles, crafters may also face a communications problem in regards to the historical textiles themselves. For the specific reproduction of historical textiles, sufficient accurate data about the textile find or surviving specimen is needed to manufacture it – or to at least make a believable interpretation of the piece. While more and more textile finds are being analysed, conserved and published and while methods and possibilities of the analysis are improving continually, most of the pieces that are published cannot be reproduced without additional data. Crucial information for the craftsperson is missing – information such as which fibre was used for a yarn, what the diameter of individual yarns is, how much twist the yarns have, how densely woven the fabric is, and so on. Without this information, it is not possible to source or spin yarn corresponding to the original yarn – and it will thus not be possible to weave a replica of the cloth. Sometimes it is not possible to retrieve all the information needed from the surviving textile, but in most cases, the scientist or conservator doing the analysis and write-up for publication will just not know what has to be included as information for a craftsperson.

This communications problem is not limited to the textiles themselves, but also to the textile tools. Spindle whorl finds might be listed stating their material and maybe their weight, but not their shape, which makes it impossible for a craftsperson to replicate the whorl. The tool problem concerns both sides: Many textile tools and implements are probably classed as "unidentified wooden object" such as distaffs, spindle sticks or other small items. Since such unidentified finds are often left out of catalogues or only mentioned without a drawing, these tools will remain unidentified and thus unknown. In addition, it will mean that future finds of possible or probable textile implements

are not recognised by archaeologists as such, since they lack the comparison finds in literature that they read. Better communication with craftspersons working with historical techniques can help historians and archaeologists to interpret and classify those tools, thus gaining better pictures of textile crafts and their part in daily life. The craftspersons can in exchange profit from knowing what implements may have been used and try working with replicas of these tools or probable tools, thus learning more about the possible or probable historical processes.

Clearly this exchange between people working the crafts and scientists analysing surviving specimens would be immensely helpful. Such exchanges are however still often very limited or even non-existent. This is partly due to lack of contact and knowledge about the other part of the field and partly due to problems in understanding the foci and concerns of the other side. It is a very common experience in academia that successful interdisciplinary work requires communication across academic field boundaries, and that this communication can be quite difficult to achieve due to different foci and viewpoints as well as differing approaches to the source material. Communication across academic field boundaries is in spite of these differences communication between parties with a similar, that is an academic, background; the parties have to agree on their questions and aims and then settle on how to approach and handle the sources. Communication between academics and craftspersons can be much more difficult than this, due to the completely different background. While the academic researcher may be interested in the social, cultural and economical implications of a textile find – for example where a pattern design came from – the craftsperson will usually focus on questions related to the making of the textile, such as whether the yarn was s- or z-spun and whether there are any indications on the type of loom used. Details and questions that will seem crucial to one party may seem irrelevant or of small importance to the other party. In addition, there is a huge difference in the basic approach between crafters and researchers: While academics must try to keep an open mind about possibilities and will usually phrase their interpretations tentatively, craftspersons may have learned one way of handling or making a type of item as the only correct way and present it as such to the researcher – who will then, from the open-minded academic background, dispute this being the only way. Here we have a clash of worlds and a miscommunication that can easily lead to the craftsperson discrediting the researcher as a stupid person who will not accept the knowledge and practical experience of the crafter, and the researcher seeing the craftsperson as someone with rigid and very limited viewpoints who is not willing to discuss other possible approaches to a task or solutions to a problem. For successful communication, patience and understanding is needed from both sides: The craftsperson has to tolerate that the researcher might need to try something that will surely not function, and the researcher has to keep in mind that while the craftsperson might not know all possible ways, he or she will have experience in the field and will know about feasible and non-feasible approaches.

A craftsperson and a researcher that join forces are working together over a much wider gap than two academics from different fields will do. As a result, this co-operation will take even more effort and patience – but the rewards of a successful communication between the parties are a considerable increase in understanding and available, useful information for both sides.

The European Textile Forum: an opportunity to bridge the communications gap

During recent years, we have seen a growing importance of experimental archaeology and the increasing use of living history as an aid to understanding and showing historical life and crafts. This was surely one of the factors that have led to a small but growing number of researchers with a strong background in crafts – persons with a double qualification that see themselves as both academics and craftspersons. They have soon become aware of the problems caused by the isolation of textile craftspersons.

Conferences for textile researchers and textile archaeologists, such as the triannual NESAT conference, are an immensely important event for meeting and exchanging knowledge with other researchers. A similar possibility for persons working with the textile crafts did not exist, though – much regretted by the academic craftspersons. This eventually led to the idea of a special mixture of conference and work meeting, geared towards the crafts perspective and crafts approach to historical textiles. What if those specialists, scattered all over Europe, got the chance to meet, to exchange technical knowledge, ideas, results of research? The chance to not only sit in a conference room listening to papers with each other, but to socialize with each other and freely exchange ideas for hours on several days? The possibility to bring and present their current project, to work on it during the meeting and have the opportunity to get feedback from colleagues? Could the crafters then form a network for themselves, making their work easier, faster and more effective – not only by sharing knowledge, but also by using their network for division of labour among themselves? And taking the idea of a meeting to further communication one step farther: What if non-crafting scientists and these professional and professional-level crafters could exchange knowledge there as well, learning more about the ‘other side’, finding a way to communicate efficiently with the others, giving feedback to each other about problems and possible solutions?

This idea soon developed into a concept for a new kind of meeting, named the European Textile Forum, which first took place with great success in Eindhoven Historisch Openlucht Museum, 2009. To entice both types of professionals – scientists and crafters – as well as Living History enthusiasts or volunteer museum presenters to come, the Forum was designed different from normal conferences or work meetings. It is a unique combination of evening lectures from professionals working with historical textiles such as scientists analysing historical textiles and craftspersons reconstructing or recreating them, and ample free time during the daylight hours to work on projects, exchange tips, tricks and techniques or hold a workshop to teach colleagues. The concept was rounded off with the possibility of holding a small market to buy tools and materials for historical textile crafts, items that are often hard to source.

The group for the Forum is purposely kept relatively small, while the framework of the Forum – a six to seven days event with the possibility to sleep on site and get full board for a very reasonable price – makes longer in-depth conversations and socialising easy.

The concept of actual textile work being done by the Forum participants requires enough space and, for some processes like fulling, dyeing or fibre preparation, outdoor

workspace is necessary due to the open fire needed or prudent due to the dirty nature of the work. This makes open-air museums or similar institutions a perfect partner for the European Textile Forum. In turn, the museum gains an additional attraction for the Forum week, and in cooperation between conference organisers and museum administration, special events such as public workshops or public demonstrations can be arranged.

Even more opportunities: archaeological experiments at the Forum

A gathering of experts and enthusiasts like the Forum opens up other opportunities as well, especially in regard to archaeological experiments connected to textile crafts. To ensure reproducibility in archaeological experiments, the usual approach is to eliminate as much as possible of the 'human factor' – including the skills and personal experiences that a craftsperson brings into the process – for example by using a contraption to shoot arrows for testing a bow, as opposed to having a person shoot the arrow (Bleicher 2006). In textile crafts, it is in most circumstances not possible to eliminate the human factor: it might be the human hand that is the most important tool used, as in spinning, or it would be too complex and too expensive to build a machine or contraption replacing the craftsperson. Often, it is also not a specific characteristic of a tool that is to be tested, but its possible uses are still not fully known – resulting in a need to have craftspersons with different backgrounds and different levels of experience work with the objects or on the projects to find out more about them.

With the human factor thus being largely non-excludable, there is only one approach left to gain relevant data – by having enough opinions and recordings of data from crafters to see if there is a general tendency, or a general agreement, about uses, functions or influences.

The basic requirements for such an experiment will inevitably result in logistical problems – most prominent of these being the need for several experienced craftspersons available during or for the experiment. For an experiment with a larger number of participants, a large enough location to accommodate the whole experiment is needed, including space to store the equipment for the experiment as well as recording and documenting it. For the collection of a large number of datasets especially in the rather time-consuming textile crafts, the experiment can easily need to run for more than one or two days. The concept of the Textile Forum was built especially to accommodate and make possible an experiment with a running time of up to six days, as evidenced by the successful running of the large-scale spinning experiment that took place during the Forum in 2009 (Kania 2010, and this volume). Other experiments might benefit not only from a large enough numbers of participants and helpers, but also from the experience and input of many crafters from different backgrounds.

The idea for the experiment planned for the Textile Forum 2012, a study of possible influences of the metal on colour outcome regarding the lead dye vats in Pompeii, was also a result of the exchanges between science and crafts experience during the Forum itself. Without the different questions coming from the crafts and science perspectives, this would never have come into existence.

Conclusion

The European Textile Forum provides a combination of possibilities and activities for a group of textile crafters and scientists that makes it easy to form new acquaintances in the field, to learn and share knowledge and to gather new experiences, see different techniques and different approaches to textile crafts procedures. The Forum is also the framework and logistical basis to run larger textile-themed experiments that require multiple participants to gather enough relevant data. The special and unique schedules and structures of this conference, with ample time to make acquaintances, talk about problems and perspectives and exchange knowledge, with the group held close together for one whole week, lets the participants connect and communicate on the level of deeper personal acquaintance than is usual for a conference or congress acquaintance. At normal conferences, the most crucial activity of visiting any conference, that is networking, is mostly limited to coffee breaks or the social events in the evenings that form part of every conference. These are usually a relatively small part of the conference due to the normally dense schedule of presentations. For the European Textile Forum, this opportunity to get in touch is core and centre, resulting in a conference that might be described by being “about eighty percent coffee break”. This may seem a very non-standard approach, but the two events in this concept that took place in 2009 and 2010 were a complete success in this regard. The two Forums have led to continued contact between the participants and to further exchanges and projects like follow-up invitations for visits and presentations, showing that the intensive contact during the Forum really aids in networking textile crafters and scientists.

The European Textile Forum has thus proved that it can serve as a networking platform, as an experiment framework, and as a knowledge base in 2009 and 2010. As the organisers, we hope for many more fruitful Forum weeks in the future years.

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The Textile Forum would not have been possible without the generous help and support of many persons from museums, open-air museums, as well as friends and family of the two organisers – and of course the enthusiasm of the participants of the past years.

References

- Bleichner, N. (2006) Optimale Anpassung oder Tradition? Technologische Aspekte antiker Bogenwaffen Mitteleuropas im Vergleich. *Experimentelle Archäologie in Europa*, 4 (Bilanz 2005), 21–26.
- Cipolla, C. M. (1993) *Before the Industrial Revolution. European Society and Economy, 1000–1700*. London, Routledge.
- Hamburger, J. F., Jaggi, C., Marti, S. and Röckelein, H. (eds) (2007) *Frauen – Kloster – Kunst*. Neue Forschungen zur Kulturgeschichte des Mittelalters. Beiträge zum internationalen Kolloquium vom 13. bis 16. Mai 2005 anlässlich der Ausstellung ‘Krone und Schleier’. Brepols.
- Kania, K. (2010) Experiment and knowledge base: bringing historical textile workers together. *EuroREA*, 7, 15–18.
- Staniland, K. (1991) *Medieval Craftsmen: Embroiderers*. British Museum Press, London.
- Windler, R. and Rast-Eicher, A. (1999/2000) Spätmittelalterliche Weberwerkstätten in der Winterthurer Altstadt. *Zeitschrift für Archäologie des Mittelalters*, 27/28, 3–84.

The Spinning Experiment: influences on yarn in spinning with a hand-spindle

Katrin Kania

The hand-spindle was the primary tool for spinning for most of human history. For such a long track record, there is astonishingly little known about the influences of this simple tool on the yarn fabricated with its help.

The spinning experiment was designed to isolate four possible influences – weight, moment of inertia, fibre and spinner – to see if any hard connections between these factors and the yarn spun can be found. It is the first experiment of this kind and the first source of statistical data to estimate connections and influences. With this data as the basis of an in-depth analysis, it can be concluded that the spinner making the yarn is the most important factor for spinning with a hand-spindle, while the three other factors have differing but altogether quite small or even no visible influences.

Spinning is, basically, making fibres hold together by twisting them into one direction. This twist presses the individual fibres in a long, thin band onto each other. With enough twist, the surfaces of the fibres, resting against each other, now produce enough friction to lock the individual fibres in place – resulting in a stable thread.

This is a very simple procedure, but underlies all spinning and, as a logical consequence, all production of woven fabrics. The most important tool used for spinning during most of human history – the hand-spindle – is just as simple as the process itself. A hand-spindle is made of a spindle stick, usually tapered at both ends, and a spindle whorl, a weight placed onto that stick that is acting as a flywheel.

Archaeological finds of the spindle sticks are very rare, since these are usually made of wood, while spindle whorls are a frequent find. For example, at Coppergate in York, England, 236 spindle whorls, but only five spindles or parts of spindles were recovered (Walton Rogers 1997). Spindle stick ends were commonly plain (Øye 1988), but in some cases, a hook or a notch are present (Walton Rogers 1997); even a knob terminal may have been used on some spindles (Øye 1988).

Most known historical whorls are made of ceramics, stone, bone or antler, or metal. Wooden spindle whorls, or at least objects that may have been used as spindle-whorls, were found at Bergen, Norway, and at Elisenhof, Northern Germany; similar objects found elsewhere have sometimes been interpreted as parts of toys like toy wheels (Øye 1988; Grenander Nyberg 1990).

When looking at the archaeological material, the variation between spindle whorls found in one region and dating to a limited timespan is usually remarkably large. A selection of 23 whorls from England, all dating to the 12th century, show weights in a range from little more than 6g up to a weight of approximately 59g (data provided by André Verhecken). The median¹ of the whorl weights is at 18.10g, the average weight² is 21.55g.

This quite considerable variation is not limited to English or medieval whorls. A variation of sizes, weights and moments of inertia can be found in all collection of spindle whorls. This can for example be seen from the histograms of whorl MIs provided by Verhecken (Verhecken 2010).

This is not limited to historical material: modern spindles used by hobby hand-spinners are showing a similar variety of whorls and whorl material as well as spindle stick ends.

Are these variations of spindle size and whorl type connected to variations in thread type, thickness or thread production? This is a question that has not yet been answered, neither for the archaeologically recovered tools nor for the modern hand-spindles.

Several writers have postulated a direct connection at least between the weight of a spindle and thread thickness, for example Munro (1994) and Crewe (1998); Andersson-Strand comes to the same conclusion after spinning tests performed by Batzer and Mårtensson (Andersson 2005/2006).

Bohnsack states, a bit less across-the-board, that it is not possible to spin thick yarn with a 4g light whorl, since it would not supply enough twist, and a 40g heavy whorl would break the yarn during drafting, since the thread would not be able to support the weight (Bohnsack 2002).

Walton Rogers, on the other hand, states that "While it is true that heavy whorls are useful for plying threads and that light whorls allow short fibres and fine yarns to be spun, it is dangerous to take the evidence too far. [...]The weight of the whorl is only one factor among many." (Walton Rogers 1997).

With the well-acknowledged importance of textiles and fabrics for the medieval society and medieval economy, it is rather puzzling that we know so little about the actual production of thread with hand-spindles. For example, often figures are given about the productivity of spinners using either hand-spindles or Great Wheels, but usually without an explanation of from where these figures are taken, or on what data the average output is based. Munro, for example, states the average output on a hand-spindle to be 110 m/h and on a Great Wheel to be about 350 m/h (Munro 1994), and Bohnsack gives average output figures of between 84 and 143 m/h (Bohnsack 2002), with the explanation that these figures were calculated from rotation frequency tests of different spindles (Bohnsack 2002, 53).

Unfortunately, no direct connection can be made between spindle whorls or spindles and the rare textile finds from archaeological contexts – which leads to the question:

Is there a traceable relationship between a specific type of hand-spindle and specific types of textiles?

To determine the amount of influence of the tool on the spinning process with a hand-spindle, a large-scale spinning experiment was designed and run successfully in September 2009. In this experiment, 14 full sets of data consisting of 10 thread samples each were gathered.

The experiment was designed to isolate the possibly influential factors a) weight of the spindle, b) Moment of Inertia (MI) of the spindle, c) difference between wool fibres from different sheep breeds, and d) the spinners using the spindles. Since the spinner – the human element – is not quantifiable, the experiment was designed to accommodate up to 20 spinners simultaneously, each spinning with the same spindle-fibre combination at the same time, to generate a large dataset that could be analysed with statistical methods. More information about the design and background of the spinning experiment can be found in (Kania 2010; Kania, forthcoming).

Weight and MI of the spindle are both mostly determined by the weight and MI of the spindle whorl. While the weight can be measured directly, MI – a figure that is determined by the object's mass distribution in relation to its axis of rotation – has to be calculated and is given in values of $\text{g}\cdot\text{cm}^2$ (grams multiplied by cm^2) throughout this article. The MI value gives information about the rotational properties of a body. To understand the basic function of the MI for spindles, it is enough to know the following: The MI is higher if the weight of the whorl is further from the axis of rotation; so a slim cylinder with the same weight as a wide thin disc has a lower MI than said disc. If a spindle with a high MI whorl and a spindle with a low MI whorl are to rotate with the same speed, more energy has to be expended for the high MI spindle than for the low MI spindle.

The two kinds of wool used were Merino wool (approx. 27–28 micron) and wool from Tyrolean Bergschaf, a wool that is coarser than Merino (approx. 32–36 micron), shown in Figure 2.1. These are the typical micron counts for Merino and Bergschaf, according to the database at <http://www.schafundziege.at/> (visited December 2011). The merino fibres were carded and combed industrially and delivered in form of top, while the Bergschaf fibres were carded only and delivered in the form of batts.

During five consecutive days, the participants spun for two hours each morning. The spindles used were designed especially for the experiment, with a reference spindle (weight and MI according to a find from 12th century London) as the basis for the design. In addition to this reference spindle with a weight of 15g and an MI of 41, four more spindles were made: two with the same weight but an MI of 5 and 188 respectively, and two spindles with the same MI as the reference, but a weight of 5g and 52g respectively. All five different spindles were used by each spinner, each of them with two different preparations of wool fibre (see Figure 2.2). The resulting thread samples are thus the results of one hour spinning time.

The resulting threads were measured regarding their length, yardage, thickness and weight; differences between wool weight before and after spinning was also recorded to track possible problems with data collection and loss of fibre during the spinning process. The approximate spinning angle (twist angle) of the resulting threads was also taken, and the threads were partly wound onto visual survey cards. Additional

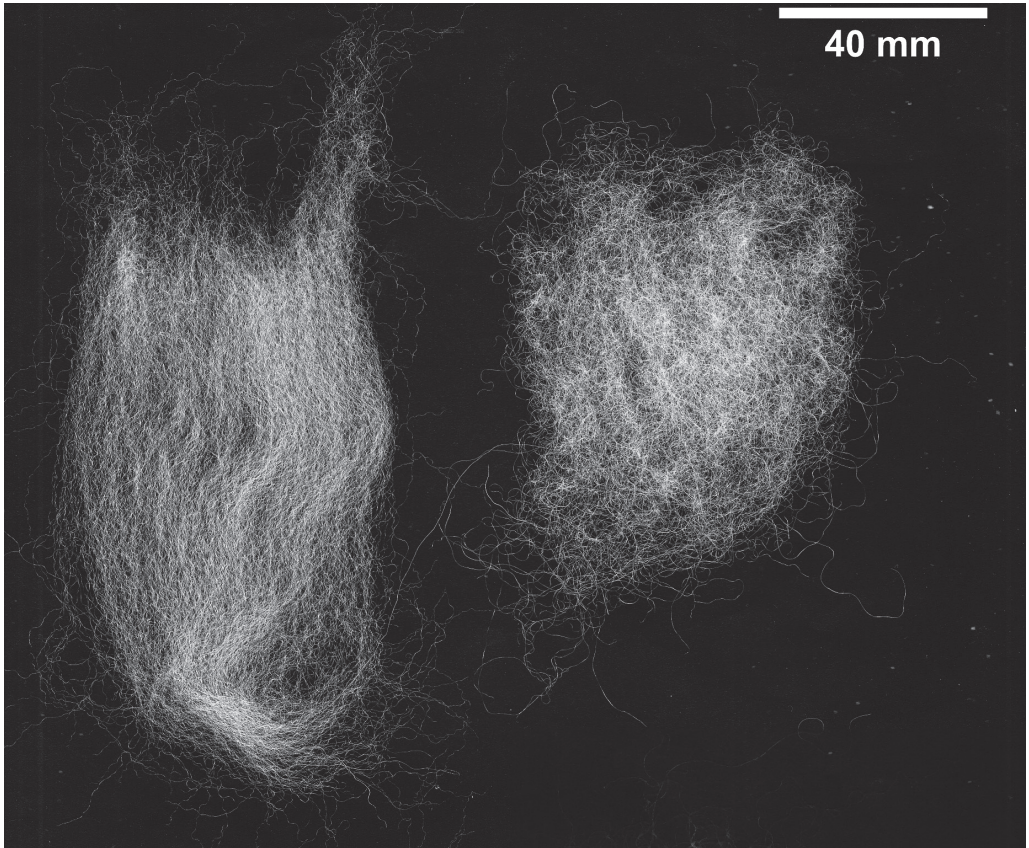


Figure 2.1. The fibres used for the experiment. Left: Merino fibres. Right: Bergschaf fibres.

<i>Session Key</i> (date/session number)	<i>Spindle Type</i> (weight/MI)	<i>Wool Type</i>
09-09-08/1	15/41	Merino
09-09-08/2	52/41	Bergschaf
09-09-09/1	52/41	Merino
09-09-09/2	15/188	Bergschaf
09-09-10/1	15/188	Merino
09-09-10/2	5/41	Bergschaf
09-09-11/1	5/41	Merino
09-09-11/2	15/5	Bergschaf
09-09-12/1	15/5	Merino
09-09-12/2	15/41	Bergschaf

Figure 2.2. Session list for the experimental spinning. Each spinner used the same spindle specimen for both sessions with the same spindle type; all spinners used the same spindle type-fibre combination at the same time.

tests, such as resistance to breaking, average strength, *etc.* were not made due to the high costs of these tests.

The data analysis showed clearly that there was no reliable connection between weight or MI of spindles and the resulting thread length, yardage, or thickness (Figure 2.3). While a heavier spindle lead to a very slight tendency towards thicker threads, the variation of thread yardages and diameters spun with each of the three weights and MI values was much bigger than any detectable tendencies, and overlapped for the most part. Regarding the fibre, it is not possible to tell whether the slight tendency towards thicker threads with Bergschaf wool that could be seen in the samples from most spinners was due to the coarser fibres or caused by the different preparation of the fibres. The results are published in more detail in Kania (Kania forthcoming).

While this is already a very interesting result, since it means it is not possible to deduce thread characteristics from the characteristics of archaeological spindle whorls, there are plenty of questions left. One of them would be if there is a discernible difference between historical threads and those spun by the modern experimenting group.

While thread thicknesses show a large variation in historical textiles as

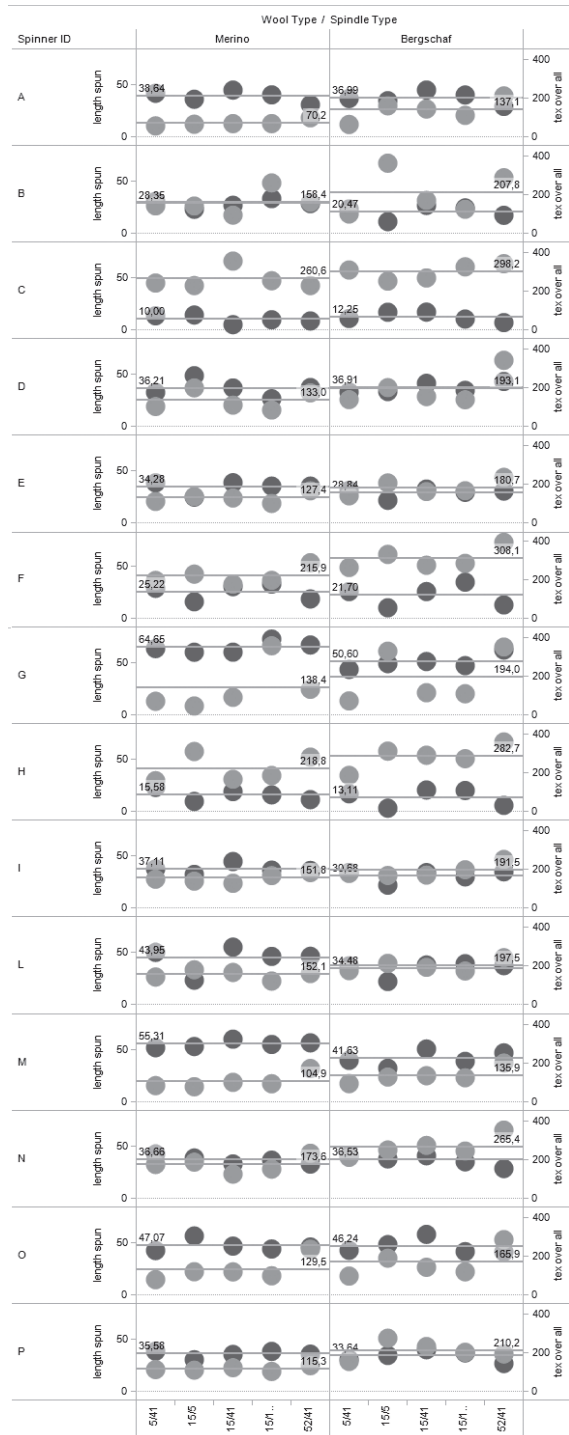


Figure 2.3. Length spun and tex (yardage) of the threads, measured over the full length of each sample. Differences between lengths and yardage are slight and cannot be safely linked to any of the changed variables.

<i>Spinner ID</i>	<i>Average Spinning Angle</i>	<i>Distribution</i>
A	20.5°	
B	29.0°	very different spinning angles on samples
C	30.0°	very different spinning angles on samples
D	22.5°	
E	16.0°	
F	22.5°	very different spinning angles on samples
G	26.0°	
H	23.0°	
I	24.0°	
L	26.5°	
M	21.5°	
N	24.5°	
O	17.5°	
P	20.2°	

Figure 2.4. Spinning angles measured for each spinner. The three spinners B, C and F showed a wide variety of spinning angles in their samples, while the other spinners had a quite narrow range of spinning angles in their yarn.

well as in modern hand-spinning and are thus not well suited for a comparison, there is significant difference between the amount of twist inserted into the yarns between the historical references and the samples produced during the experiment. The amount of twist is evaluated using the spinning angle or twist angle, a measurement also used to characterise threads in archaeological textiles. This figure gives an indication of how much twist was introduced during the spinning process; the higher the spinning angle number, the more twist. To find the spinning angle, the angle between the slant of the fibres and the edge of the thread is measured.

Unfortunately, this measurement is often not taken or at least not published. A notable exception to this is the publication of the finds from Norse Greenland, published in *Woven into the Earth*, where spinning angles are given for almost all of the textiles. Typically, the threads were spun with an angle of about 40–50° in z-direction for the warp and 30–40° in s-direction for the wefts. Lower or higher spinning angles were only rarely employed in this find complex (Østergård 2004).

In comparison to these rather high spinning angles, almost all between 30° and 50°, the samples from the spinning experiment are very softly spun (Figure 2.4, Figure 2.5). The Bergschaf wool samples have a tendency to be more twisted than the Merino samples which might be linked to the shorter fibres or to a slower drafting speed with the same spindle speed due to the different fibre preparation. Average spinning angle across all the experiment samples was 23.16°, median spinning angle was 20°. The average angle for Merino samples was 21.24° (median 20°) and for Bergschaf 25.07° (median 25°). There is however again a considerable overlap between spinning angles of Merino and Bergschaf threads, and there is no connection between spinning angle and spindle types.

This rather low spinning angle, compared to historical threads, might be due to a

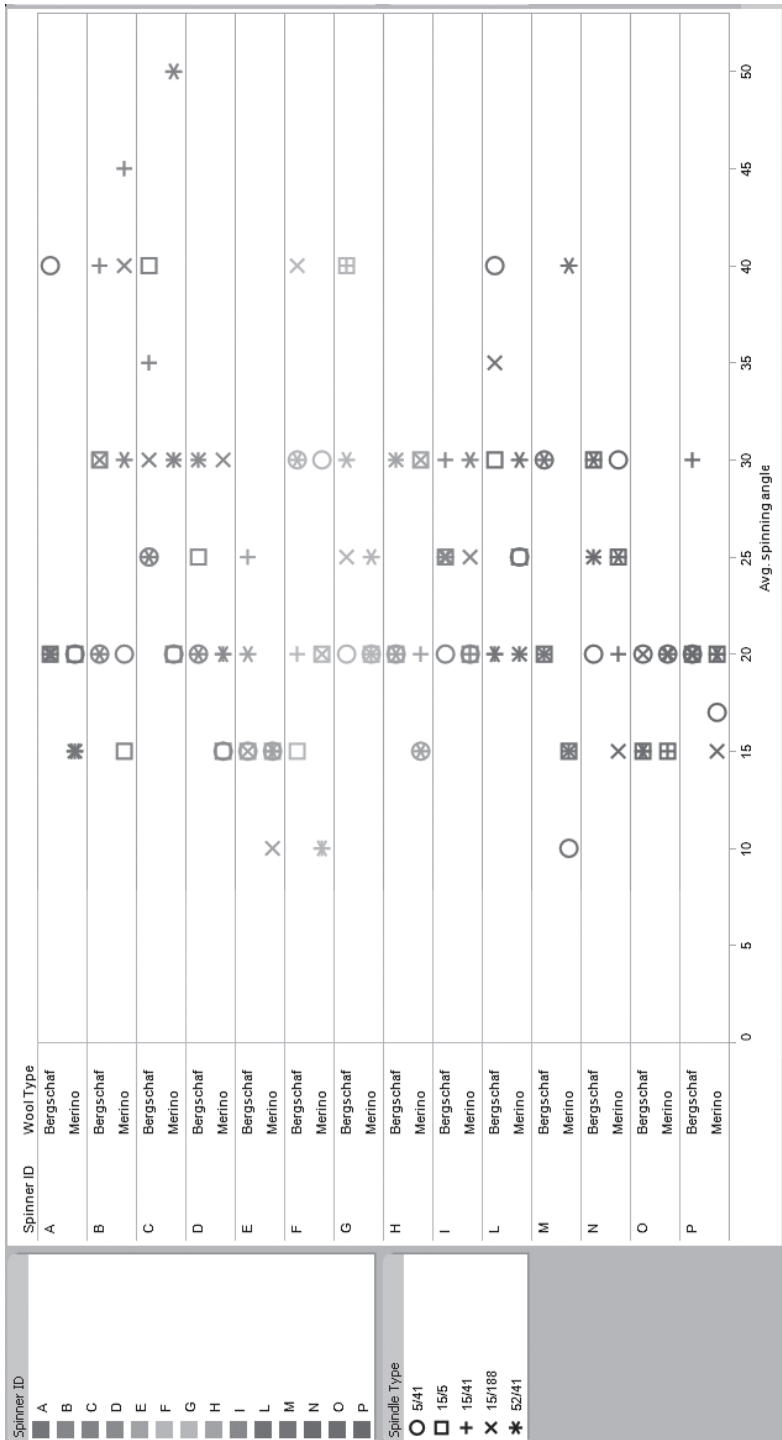


Figure 2.5. Spinning angle of all spinners in all samples. Spinning angle is higher (tighter spun threads) for Bergschaf wool for all spinners.

different approach, different use, or different aesthetics today. Hand-spun yarn is today often used for knitting, a technique that does not put much strain on the spun thread and thus is suitable for soft yarns with little twist. Other uses, like tablet-weaving or weaving, put much more strain on the individual threads.

In modern hobby spinning, amounts of twist are sometimes given as a count of twists per inch (abbreviated TPI). However, spinning angle or twist angle is also used to classify yarns. One recommendation for twist angle for singles yarn to ply into sock yarn for knitting is to spin for a twist angle of 20 degrees; yarns with more than 30° spinning angle are called ‘very high twist yarns’ in the same text (<http://www.hjsstudio.com/twistangle.html>, December 2011). A similar approach to twist is given in another website, where twist for single yarns is recommended to be “Just enough to hold it together, or alternatively, when you hold the just-twisted length loosely, it only tries to twist back on itself loosely” (<http://askthebellwether.blogspot.com/2007/02/how-much-twist-does-singles-need.html>, December 2011). The modern emphasis on spinning to make low-twist yarns is possibly also connected to the high valuing of soft yarns by modern hand-knitters, since softly spun yarns will have a softer feel to them.

This difference between historical yarns and modern hand-spun yarns shows both that the typical thread types may change over time and that they will be influenced by, and change with, the intended use of the yarn. Changing the twist to a higher spinning angle should in theory be a relatively easy thing to do for a spinner, since all that is necessary is waiting a little while after drafting to let additional twist enter the spun yarn. This can be done after the normal spinning or drafting process and before winding up the yarn. Adding additional twist does thus not necessarily mean a change in the drafting process or different handling of tool and material and will therefore not change the thickness or yardage, or the evenness, of the thread.

However, there is even more information that can be gathered from the threads spun during the experiment. One sign of high quality in hand-spinning is the evenness of the thread. Measuring and analysing the lengths spun by the participants already shows that, contrary to the expectations of all persons involved, the sessions with spindles that were troublesome and problematic for the spinners to use did not generally result in much shorter lengths of thread. It was however quite obvious that in the sessions with ‘troublesome’ spindles, the amount of chatting between the participants was much smaller, sometimes resulting in almost complete silence, while the sessions with ‘easy’ spindles were filled with talking, joking, and friendly banter. Increased concentration on the spindles was probably the reason for both the amount of talk between spinners and the rather small differences in output of yarn.

The obvious question then is: if the spinners have an output almost as high with ‘bad’ spindles as with ‘good’ spindles, is there a noticeable difference in the quality that can be seen by analysing the evenness of the thread?

Measuring thread thicknesses and thread thickness changes is, as already mentioned, far from trivial. While thread thickness can be approximately measured by the wraps-per-inch or wraps-per-3-centimetre measure, the common modern method to measuring the evenness of thread is to acclimatise the sample to controlled laboratory conditions, cut pieces of an exact fixed length, weigh them on high-precision scales and calculate the tex value of each piece. This procedure is commonly used in modern textile analysis

(Pers. Comm. Schödel-Guthke 2010). Variation of thread yardage and thus the evenness of the thread is then calculated from these collected data.

This procedure is only possible under the controlled humidity and temperature of a laboratory, and high-precision equipment is needed for measuring. The smaller the pieces measured, the higher the resolution of the variation change data – but with smaller sample pieces to weigh, the margin for error due to slight weight changes or mis-measures is again greater. Finally, apart from the considerable amount of time needed for this procedure, the thread samples have to be destroyed for this method. All this was reason enough not to do a classic thickness/yardage variation evaluation on the samples from the spinning experiment.

There is, however, an alternative method for sampling thread thickness data using image analysis software. Image analysis software is often used to help evaluate and process the data in medical and biological surveys, but is also used in other branches of science, in quality management and in security procedures.

For the thickness analysis of the experiment samples, the equipment used was a colour LED scanner set to 1200 dpi, used for scanning in the visual survey cards; the programme ImageJ, a public domain open source programme with a custom macro to facilitate the process; table calculation or database software (such as Excel) to evaluate the results; Tableau Public to visualise data; and visual survey cards from Textechno.

Thread thickness is evaluated by transforming the picture into black and white through running a filter converting the picture to binary, then drawing a box containing each thread sample and counting the number of black and white pixels in each vertical pixel column in the box. With the known height of the box in pixels and a known factor to convert pixel height into mm that can either be taken from the known scanner resolution or a known length in the scanned sample, this enables the researcher to read out approximate thread thickness along each thread sample.

The basic process of the digital image thickness analysis, listed in more detail, is as follows:

The thread sample is used to fill a visual survey card with a high contrast to the yarn colour (in this case, the black cards were used as background for the white yarn). The survey cards are scanned in using a normal optical scanner, set to 1200 dpi resolution, and saved as .tiff or .png file, not as .jpg file (since this file type uses a compression algorithm that leads to data loss when saving).

The files are opened in ImageJ and processed by first finding the scale of the image. This is done by selecting the grey rectangle in the Textechno logo at the bottom of the card and setting the width of this selection as a known length of 24 mm.

The image is then cropped to remove the top and bottom of the card as well as the usually slightly curved left and right ends of the yarn sections. The image is then transformed into a binary image, giving all the thread samples the grey value of 255 (true black) and all the background the value of 0 (true white). During this transformation, stray fibres sticking out of the threads are already partly eliminated. To have an indication of how much is changed by the transformation, the overall grey value of the image is recorded before and after the process. To further reduce stray fibres, a filter to reduce noise is then run, removing the outliers by sampling

over a 6 pixel radius. After this filter, the overall grey value is recorded again. The sampled grey values can also be used to indicate the fuzziness of the sample.

A region of interest (ROI) is then generated from each thread piece. This highlights all the 47 yarn sections on the card. Then the ROIs are turned into bounding boxes (the smallest rectangle enclosing the yarn section), and the height of each bounding box is written to a file and saved for later processing.

Following this, a plot can be made of each bounding box, giving the average grey value for each of the 3084 vertical pixel columns ('slices') in the bounding box. Using the known height of each bounding box and the grey value, it is now possible to calculate the thread thickness in pixels for each slice; and with the known relation of pixels to mm, this can be transformed into the thread thickness in mm. With the dataset thus generated, it is possible to compare thread thicknesses and evenness between the samples of each spinner and between spinners.

While this procedure also has its fair share of inaccuracy, it is a non-invasive possibility to generate many thread thickness readings in very little time, using quite readily available equipment. Furthermore, since the algorithm of the conversion to binary picture format is always the same one, fluffiness and stray fibres sticking out of the thread surface are registered in the same way and with the same impact on all samples, thus making the data from several persons doing similar analysis easily comparable with results that should be quite reliable. For the filtering procedures, settings were selected to remove as much of stray fibres and fluffiness as possible without altering the size of the threads even for thin thread samples. To obtain accurate results, it is necessary to scan the visual survey cards with 1200 dpi resolution; this will yield a ratio of 47.244 pixels per mm. For thin threads, a 600 dpi resolution will be too low and result in disproportionate inaccuracies.

Figure 2.6 shows the lengths spun by each spinner. For a first evaluation both of the process and of the thread quality as evidenced by its evenness, the samples of four spinners were selected – two spinners with large variation of length output and two spinners with rather small variation. These spinners were C, G, L and P. In addition, a fifth spinner – Spinner B – was selected by chance.

From the thickness measurements of each survey card, it is possible to calculate both the average thickness and the standard deviation of the samples (in mm). This gives a first overview of how irregular the spun threads were. However, a standard deviation of 0.3 mm on a thread of average thickness of 0.5 mm is resulting in a much more uneven thread than the same standard deviation on a thread that is 1.5 mm thick on average. Thus a better figure for evaluating the evenness is the relative standard deviation, calculated as $\text{st.deviation} / \text{average thickness}$. For the four spinners in question, the averages and standard deviations (in mm) and the relative standard deviations are as shown in Figure 2.7; Figure 2.8 shows the maximum and minimum relative standard deviation of the five spinners and thus indicates the range of deviation.

The higher the relative standard deviance, the more uneven a thread will look. Relative standard deviations of all the five spinners evaluated thus lie between 24% and 59% of the thread thickness.

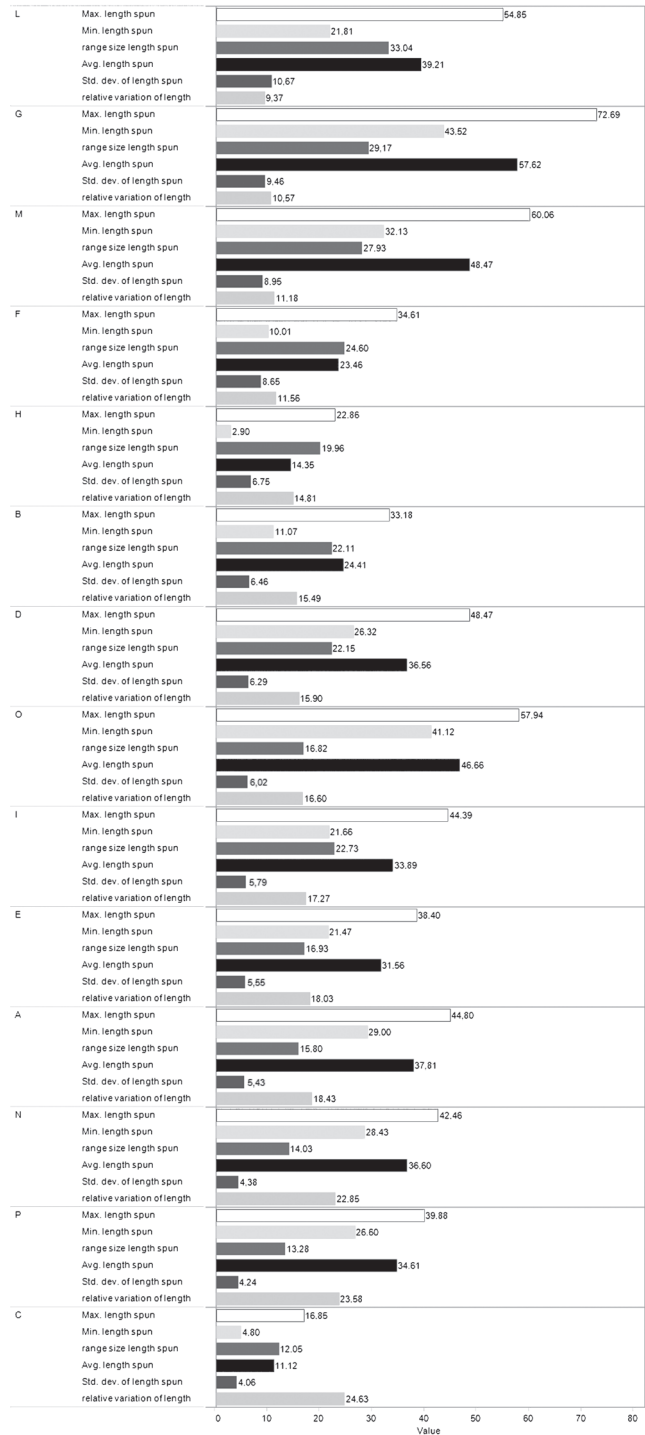


Figure 2.6. Graph showing the maximum, minimum and average length spun by each spinner, as well as the range size (difference between max and min length), the standard deviance of lengths spun and the relative variation of length (calculated as $100 * (\text{st.dev} / \text{average})$). Spinners are ordered from smallest to largest relative variation of length.

<i>Spindle Type</i>	<i>Session</i>	<i>Value</i>	<i>Spinner B</i>	<i>Spinner C</i>	<i>Spinner G</i>	<i>Spinner L</i>	<i>Spinner P</i>
15/41	09-09-08_1	average	0.5089	1.0208	0.5265	0.9577	0.6417
		st.deviation	0.1700	0.4184	0.1337	0.4490	0.1766
		rel. st.dev	0.3340	0.4099	0.2540	0.4688	0.2752
	09-09-12_2	average	0.7500	0.9525	0.5753	0.9056	1.1204
		st.deviation	0.2113	0.3367	0.2020	0.4466	0.4065
		rel. st.dev	0.2818	0.3535	0.3511	0.4932	0.3628
52/41	09-09-08_2	average	1.0674	0.9854	1.2266	1.1474	1.0182
		st.deviation	0.3871	0.3979	0.3463	0.6774	0.4196
		rel. st.dev	0.3627	0.4038	0.2823	0.5904	0.4121
	09-09-09_1	average	0.7479	0.8438	0.5921	0.8200	0.8167
		st.deviation	0.2051	0.3935	0.1417	0.3002	0.2458
		rel. st.dev	0.2742	0.4664	0.2393	0.3661	0.3010
15/188	09-09-09_2	average	0.7008	1.0240	0.5341	0.8980	1.0459
		st.deviation	0.2474	0.3671	0.1994	0.4426	0.3171
		rel. st.dev	0.3530	0.3585	0.3734	0.4929	0.3032
	09-09-10_1	average	0.9686	0.8838	1.5033	0.7891	0.6923
		st.deviation	0.2691	0.3133	0.3843	0.3178	0.2036
		rel. st.dev	0.2778	0.3545	0.2557	0.4027	0.2942
5/41	09-09-10_2	average	0.6243	1.1552	0.4440	0.8867	0.8331
		st.deviation	0.2385	0.3937	0.1839	0.4392	0.2872
		rel. st.dev	0.3820	0.3408	0.4141	0.4953	0.3447
	09-09-11_1	average	0.7407	0.8408	0.5124	0.8324	0.8231
		st.deviation	0.1802	0.3368	0.1437	0.3108	0.2450
		rel. st.dev	0.2433	0.4006	0.2805	0.3734	0.2977
15/5	09-09-11_2	average	1.6471	0.9917	1.3798	1.0522	1.4383
		st.deviation	0.7021	0.3708	0.3956	0.4896	0.6348
		rel. st.dev	0.4263	0.3739	0.2867	0.4653	0.4413
	09-09-12_1	average	0.7578	0.9369	0.3466	0.9356	0.7709
		st.deviation	0.2382	0.4134	0.1122	0.4736	0.2832
		rel. st.dev	0.3143	0.4413	0.3236	0.5062	0.3674

Figure 2.7. Spinners' basic thread data, calculated from thicknesses of the threads spun. Average and st. deviation are given in mm. Data is ordered by spindle type; sessions ending with '_1' were with Merino fibre, sessions ending with '_2' with Bergschaf fibre.

	<i>Spinner B</i>	<i>Spinner C</i>	<i>Spinner G</i>	<i>Spinner L</i>	<i>Spinner P</i>
Minimum rel. st.dev	0.2433	0.3408	0.2393	0.3661	0.2752
Maximum rel. st.dev	0.4263	0.4664	0.4141	0.5904	0.4413

Figure 2.8. Maximum and minimum relative standard deviance of the five spinners surveyed. Spinner C and spinner L show a higher minimum than the other three spinners, but only spinner L has a significantly higher maximum relative st.dev than the other four.

This gives a first approximation of the evenness of a thread; however, it does not yet give any hint as to whether the unevenness is caused by thread irregularities that are thinner than average, thicker than average, or by slubs. For this, some other way of evaluating the data is needed.

Since the number of datapoints is so large for each sample, a histogram can be employed. For a typical histogram, the data is classed into ‘bins’ of a set size, and the number of data values in each bin is graphed. This makes large sets of data easier to evaluate, since small differences between data points are removed from the visuals.

For thread evenness evaluation, however, choosing the correct bin size is not trivial. A thread with the same thickness difference, for example ± 0.2 mm, looks much more even when the absolute thread thickness is higher. A thread with a basis thickness of 0.4 mm will halve or double its thickness, while a thread with basis thickness of 2.0 mm will only lose or add 10% to its normal thickness. To be able to really evaluate the evenness of the threads, some way of calculating the relative thickness difference is thus necessary.

This can be achieved by graphing a histogram using the following formula for the values:

$$\frac{(d - \mu)}{\mu}$$

with d the thread thickness and μ being the median of the dataset.

The median is used instead of the mean average because it is less influenced by outliers in the data. While the mean average is the sum of all values divided by the number of values, the median is defined as the mid-point – in a list of all the values ordered from highest to lowest, the median cuts this list exactly in half. For example, in a list of values that goes 1, 2, 3, 4, 100, the average is $(1+2+3+4+100)$ divided by 5, which is 22. In contrast to this, the median of the same dataset is 3.

The formula given results in a theoretical minimum value of -1 (thread thickness 0) and a theoretically unlimited maximum value. A value of 0 occurs when the thread thickness equals the median of the dataset. A value of 1 means the thread thickness is double that of the median. The higher the result, the thicker the thread is in comparison to the median; and since the results are normalised by the calculation, the thickness histograms can be compared across all spinners.

For the histograms, a bin size of 0.75 was chosen. While too large bins will yield an unclear picture of the distribution, too small bin sizes or badly chosen bin limits can

result in odd gaps in the histogram and ‘sawtoothed’ graphs. The chosen size proved to be a good medium for the data yielded by the four samples.

From looking at the histograms, it is very obvious that thickness variations are more often going towards a thicker than towards a thinner thread. With the bin at 0 being the median thickness of the spun thread, a value of -0.5 means a thread that is 50% thickness of the median, a value of 0.5 means a thread that is 150% the thickness of the median thread.

On first glance, most of the threads spun by the four spinners evaluated in this first analysis seem to show much higher counts of thicknesses higher than 0.5 or even higher than 1.0 than thicknesses lower than -0.5 – thus, there seems to be a strong bias in the unevenness. In the histograms, this is very much evident by a steeper slope on the left side and a shallower, sometimes even curved slope on the right side.

To get a better overview of the outliers and the distribution of the unevenness, the ‘outlier counts’, that is the thickness counts in the bins under -0.525 and over 1.05, were evaluated (corresponding to thread thinner than half the median thickness and thicker than double the median thickness). When looking closer at this data, it soon becomes clear that there is not always more ‘thick unevenness’ than ‘thin unevenness’. In some cases, there is even significantly more ‘thin bits’, as in the sample B 09-09-11/2 or the samples P 09-09-08/2 and P 09-09-11/2. There is, however, no discernible pattern regarding the variations in thread thickness – it seems to be depending almost exclusively on how a spinner personally copes with a given combination of spindle and fibre.

One spindle that was given particularly bad reviews as a troublesome tool by the spinners was the spindle 15/5 (15g, MI 5), dubbed “the spindle from hell”. The thickness variation data shows that for spinner B, the first session with this spindle had the highest outlier counts of all samples. For other spinners, this did not make as much of a difference: Spinner C had the highest outlier count in session 12/1 (also with spindle type 15/5), spinner G had the highest outlier count in session 10/2 (spindle 5/41), and spinner P had two significantly higher outlier counts, one in session 08/2 (spindle 52/41) and one in session 11/2 (spindle 15/5).

A kind of training effect is also more or less discernible (Figure 2.9). In many cases, the second hour that a spinner used one of the experiment spindles, the outlier count total is lower than the count for the first hour. This is, however, not universally true – in some cases, the outlier count is higher the second time a spindle is used (Figure 2.10). This is the case for spinner G with both the 15/41 and 5/15 spindle type, spinner P with the 15/41 spindle type, and spinner C (the beginner spinner) with spindle types 52/41, 5/41 and 15/5. Spinner B shows significantly smaller outlier counts for the second session with each of the five spindles.

Conclusion

While the thread thickness variation is much more pronounced in some samples than in others – even calculated as to give the relative thread thickness variation – there is no indication of a connection between thickness variation and spindle weight, spindle MI or fibre.

All the analysis of the spinning experiment up until now points to spinning being a

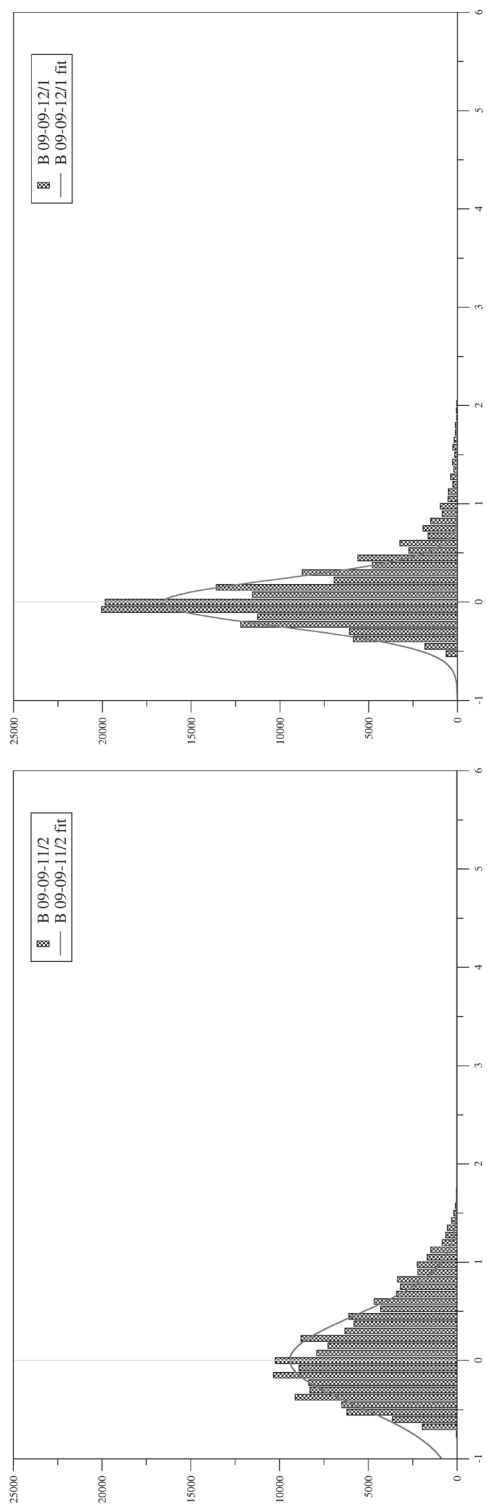


Figure 2.9. Histograms of spinner B, showing the relative thread thickness counts for the two session with spindle type 15/5. The line indicates a Gauss curve fit to the histogram.

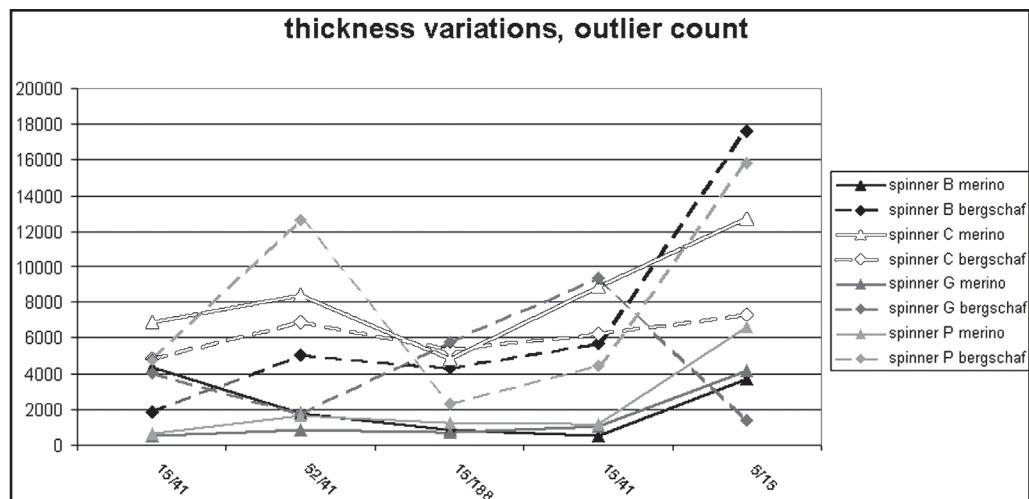


Figure 2.10. Total outlier count for Merino and Bergschaf wool for the five spinners B, C, G, L and P. There is no clearly visible pattern regarding outlier count relative to spindle type or wool used; variations in outlier count seem to be connected to the spinner's reaction to a given combination of spindle and fibre.

craft where most of the outcome depends on the person performing. When a spinner is given a combination of spindle and fibre, even if the outcome of spinning with this combination is known from other spinners, it is not at all possible to predict thread thickness, thread type or thread quality.

There is no obvious explanation as to why heavy spindles are so often associated with thick yarns both in archaeological literature and popular textile history literature. According to the results of the spinning experiment, there is no direct link between weight and thread yardage or diameter. One possible reason is that this conclusion is taught as a basic fact to new spinners, therefore setting a firm association in their minds. Interestingly, even though a connection between spindle weight and thread thickness is accepted by many spinners as a basic fact, it is not expected for a spinner's thread to grow slowly but continually thicker when a spindle is getting filled continuously. Maybe the conclusion is partly due to our modern, mechanised society where we assume that the equipment used will have a strong influence on the finished product. While this is often true for complex machinery, it is not necessarily the case with very simple tools. In that respect, a spindle might be compared to a knife: While different types and sizes of knife will be best suited for different kinds of work, there is a very large overlap in the things that can be done with any knife – and the outcome mostly depends on the skill of the user.

Which leads to the question: If spindles are actually of so little relevance for the resulting thread, why are there significant variations between spindles in the archaeological finds?

There is no easy answer to that question – though there are a number of possibilities. The spinners' comments from the spinning experiment have shown that a whorl with a low MI is perceived as very fast spinning, while one with a high MI is perceived as a slowly spinning whorl. A spinner that prefers slow drafting and thicker threads will probably feel more comfortable with a different spindle than a fast-drafting spinner who prefers very thin threads. A different spindle stick can also change the rotation speed of a spindle due to different finger grips and finger speeds when flicking it into turning motion.

So one type of spindle might be better suited to a method of spinning preferred by a given cultural or regional group; spindle weights may differ to give the spinner finer control over the thread strength. A special combination of weight and MI may be easier to achieve with one material as opposed to another material for making whorls. Finally, 'maker traditions' may have played a part in determining form and weight of a whorl.

Spindles from historical context are varying in size, material, weight and MI – even for a limited area and a limited time period, there is usually no 'typical' spindle or spindle whorl. Recorded and documented spindle whorl assemblages may be widely varying for the same era in nearby localities or different eras and the same locality, or may remain relatively constant over longer periods of time; assemblages may span a rather large variety of weights and MI, or show several clusters of weights/MI. Histograms of different assemblages of whorls, grouped according to their MI, are published in (Verhecken 2010).

The spinning experiment shows rather clearly that evaluating spinning is a difficult process, and that a thread type, thickness or quality cannot be guessed – may even not be influenced at all – by the tool used by a spinner. Spinners may work well with a given tool or may not work well with it at all; however, their self-assessment of the output with a given spindle is also not reliable. This is, on the one hand, a pity – a clear, well-defined interconnection between specific threads and specific types of spindles or spindle whorls would have been a welcome help in evaluating both textile finds and finds of textile tools. On the other hand, the results of the spinning experiment show us that crafts processes and craft products should not be seen as a 'black box' model where a predefined tool and known raw materials result in a predictable end result. The products of historical crafts are mostly defined by the crafts person or persons involved in the process – with the tools of the craft being just that: a device used in production that does not necessarily leave a trace.

Even though there are no discernible connections, the methods and software tools used and developed for the analysis of the spinning experiment threads may be developed and adapted to help document and evaluate other textiles, possibly even historical threads and weaves. The ImageJ macro and description of the process are available from the author or from the website www.textileforum.org, where the full dataset of the spinning experiment can also be downloaded.

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Notes

- 1 The median is a statistical computation point; half of the values of the dataset lie above the median, and half lie below the median. Additionally, the upper and lower half can be divided again with a median, resulting in four quartiles.
- 2 Averages are calculated by addition of the data values, divided by the amount of values. Average and median can differ considerably with some datasets.

Sources for materials and programmes used

ImageJ is a free open-source programme; information, user guide and download of the programme at <http://rsbweb.nih.gov/ij/>.

The survey cards used for the thread samples can be ordered via mail from Texttechno; the company website is <http://www.texttechno.com/cms/index.php>.

The public version of Tableau (data visualisation), with limited import and export functions and storage of data and results only possible on the Internet, can be downloaded from <http://www.tableausoftware.com/public>.

Graphs can also be plotted using XMGrace, a linux/unix programme that is free and open-source; the programme can be downloaded at <http://plasma-gate.weizmann.ac.il/Grace/>. For a Windows computer, XMGrace can be run using Cygwin (<http://cygwin.com/>), a Linux emulator for Windows machines.

References

- Andersson, E. B. (2005/2006) *Technical Textile Tools Report Archontiko*. CTR Centre for Textile Research Copenhagen.
- Bohnsack, A. (2002) *Spinnen und Weben. Entwicklung von Technik und Arbeit im Textilgewerbe*. Bramsche, Rasch Verlag.
- Crewe, L. (1998) *Spindle Whorls. A study of form, function and decoration in prehistoric Bronze Age Cyprus*. Jonsered, Paul Aström Förlag.
- Grenander Nyberg, G. (1990) Spinning implements of the Viking Age from Elisenhof in the light of ethnological studies. In Walton, P. and Wild, J. P. (eds), *Textiles in Northern Archaeology. NESAT III: Textile Symposium in York, 6–9 May 1987*. London, IAP Archetype Publications.
- Kania, K. (2010) Experiment and knowledge base: bringing historical textile workers together. *EuroREA*, 7, 15–18.
- Kania, K. (forthcoming) Determining Influences on Yarn spun on a Hand-Spindle – Results of a Large-scale Spinning Experiment. *Conference Proceedings OEGUF 2010*.

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- Munro, J. H. (1994) *Textiles, Towns and Trade. Essays in the economic history of late-medieval England and the Low Countries*. Aldershot, Variorum.
- Østergård, E. (2004) *Woven into the Earth. Textiles from Norse Greenland*. Aarhus, Aarhus University Press.
- Øye, I. (1988) *Textile Equipment and its Working Environment, Bryggen in Bergen, c. 1150–1500*. Bergen, Norwegian University Press.
- Schödel-Guthke, S. (2010) pers. comm. Textilanalyse Münchberg.
- Verheeken, A. (2010) The Moment of Inertia: a Parameter for the Functional Classification of Worldwide Spindle-Whorls. In Andersson Strand, E., Gleba, M., Mannering, U., Munkholt and C. Ringgaard, M. (eds), *North European Symposium for Archaeological Textiles X*. Oxbow Books, Oxford.
- Walton Rogers, P. (1997) *Textile Production at 16–22 Coppergate*. York, Council for British Archaeology.

Structural Considerations for Understanding Historical Tablet Weaving

Sarah Goslee

During the many centuries during which tablet weaving has been practiced, back at least to the 9th century BC, ever-inventive weavers have developed a multitude of complex techniques. Clear and consistent methods of describing the structural attributes of tablet-woven bands enable the historian and reenactor to communicate clearly. Relating structural attributes to potential methods of production allows both the accurate reproduction of historical bands and the recognition of subtle features that aid in determining which of many possible techniques of production may have been used.

Five attributes of tablet weaving determine structure, three that characterize the warp setup, and two that describes the weaving process: tablet shape, holes threaded, and warp threading direction for setup; and for weaving, turning sequence and positioning of adjacent tablets within that turning sequence. A consistent classification has been developed for each aspect of the process of tablet weaving, and its applicability to description of common tablet-woven structures from extant bands demonstrated.

As with many textile techniques that rely only on simple equipment, multiple methods of working can produce identical results. Often errors or minor structural differences can help to distinguish among these methods when the relationship between structure and production is clearly understood.

Introduction

The history of tablet weaving is long and complicated, and it will probably never be possible to answer some of the most interesting questions: Where did it originate, and when? Did it start in one place and spread to other areas, or was it developed independently in different times and places? There are thousands of known tablet-woven bands, but this art is so complex and widespread that trying to organize it is a real challenge. There are three major problems with trying to develop a synthesis:

1. Textile material is very poorly preserved in most archaeological contexts, so it's amazing that there are as many surviving pieces as there are. Every-day pieces were probably used as long as possible then discarded, so the available material may be biased toward elaborate and expensive items.
2. Knowledge of textile history and conservation has improved greatly over the last century. Early finds were often poorly described and badly conserved, so detailed information is unavailable.
3. Archaeological and ethnographic textile material from some geographic areas may not be available to scholars from outside that region.

Given those difficulties, how can available material be categorized to make sense of any patterns in time, space, and structure? There are three kinds of evidence for tablet weaving, each with its own strengths and weaknesses. Textile finds can be the most informative: it may be possible to determine the width and length of the band, number of tablets, materials used and structure. Small or poorly-preserved fragments are common, and not much can be learned from them. Some structures, such as tabby (plain weave, with warp and weft interlacing alternately), can be woven in many ways, including on tablets, so a band alone may not be enough to establish method of production. Equipment has sometimes been found: tablets would seem to be an unambiguous indicator, but some tablets may have been used for other textile crafts like rope-making, or as ornaments. The third kind of evidence is descriptive: a written or pictorial depiction of a weaver at work. Such descriptions are definitive evidence that the artist knew about tablet weaving, but may not represent an actual weaver in context.

Tablet weaving reached its peak in complexity and abundance in northern Europe from the 4th to the 15th century, but is known from the Middle East, Central and Southeast Asia and the Indian subcontinent up to the present day. No tablet weaving is known from North or South America, although indigenous cultures of both continents are well-studied and ethnographic material is readily available. No tablet weaving is known from Australia, or from central and southern Africa or eastern Asia, although Africa and Asia would both be easily within the possible range of transmission. Is the lack a real absence, or a shortage of knowledge? A complete and accurate characterization of structures from surviving bands can help to delineate potential transmission of weaving knowledge through the times and places from which tablet weaving is known.

Structure

There are a few named tablet weaving structures commonly recognized by modern scholars of this technique including warp twining, doubleface and 3/1 broken twill. Other less-familiar structures are known from premedieval and medieval contexts, and many more structures are possible, but not represented among historical finds. Structures can be analyzed and classified systematically. 'Structure' refers here to the physical attributes of the band, including interlacements and twining, regardless of the color patterns that may appear. Decorative color patterns are an essential feature of the the appearance of a tablet-woven band, but they are not a structural component: the

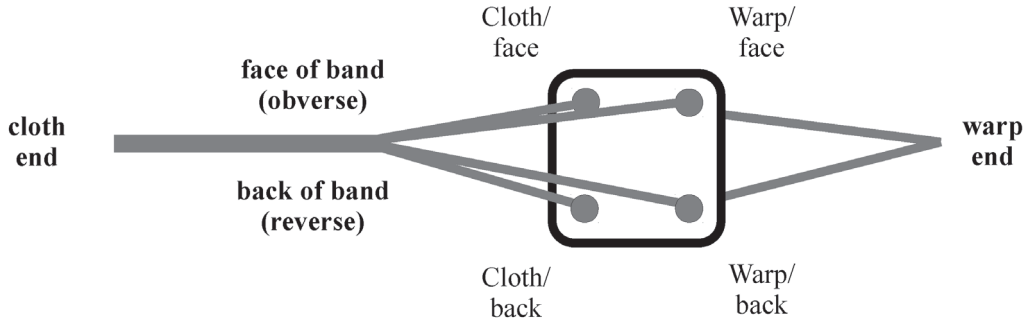


Figure 3.1. Standardized nomenclature for tablet weaving based on fixed characteristics of the weaving itself: cloth and warp ends define one axis, and face and back of band the other.

structure would be the same even if the warps were all identically colored. A doubleface band, for example, is of that structure regardless of whether it is solid or patterned.

Weavers recognize two basic kinds of structure: warp-twined, where the tablets are turned all together, and turned patterns where tablets are turned individually. Doubleface and 3/1 broken twill are the most common examples of turned patterns, but there are many more: diagonal patterns, Snartemo-style patterns, Hochdorf pebble weave, and even rarer structures. Surface embellishment such as brocading adds an additional layer of complexity. Description of textile structures inevitably conflates finished structure and means of production, but as the usual objectives are to understand how a band was woven and to be able to create a replica, such juxtaposition is more helpful than otherwise.

The structure of tablet weaving is determined by five main characteristics. The first three concern the way in which the warp is set up, while the last two describe how it is manipulated:

- the shape and number of holes in the tablets.
- which of the holes contain warp threads.
- the threading direction of the warp threads in each tablet.
- the turning sequence each tablet follows.
- position within the turning sequence of adjacent tablets.

Basic terminology

All terminology and figures assume a common frame of reference based on necessary characteristics of the warp itself (Figure 3.1). Generally the weaver sits at the cloth end of the warp for easy manipulation of weft and tablets, with the warp end fixed to a point. All figures assume that the warp is viewed from the right side, with the cloth end to the left and the face of the band to the top. Using this arrangement, the weaving progresses from left to right, in the direction English speakers are used to reading. Rather than being labeled on the tablet itself, the individual holes can be specified uniquely by reference to the end and face nearest.

Components of Structure

Tablet Shape

A weaving tablet can be made in the form of any regular polygon, and any combination of holes can be threaded, from only one to all of them. The vast majority of weaving tablets are square, with one hole per corner. Triangular tablets have been found, and there is historical evidence for the use of six- and eight-holed tablets as well. The structural classification here can be applied to tablets of any shape, but is illustrated only for the nearly-universal square tablet.

Square tablets can produce two different sheds: the usual single shed created when tablets are used flat, and the paired shed created by tablets on their points (Figure 3.2). Higher-sided polygons can produce greater numbers of sheds. Square tablets used flat (single shed) are the most common form, and the only one considered further here.

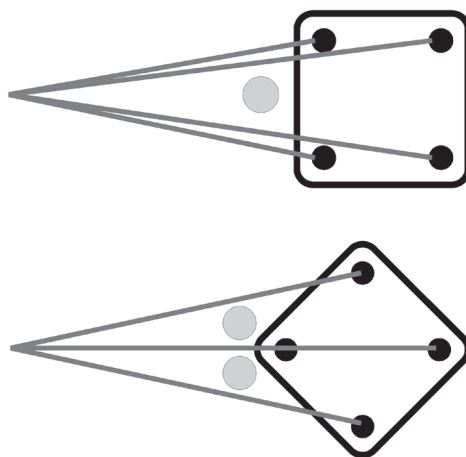


Figure 3.2. Possible sheds created by four-hole tablets used flat or on their points.

Tablet Threading

Even with four-hole tablets, there are several possible threading arrangements, since not all holes need to contain warp threads. A four-hole tablet can contain 4, 3, 2 or 1 warp threads, and two arrangements of two threads are possible (Figure 3.3). In archaeological material and among modern weavers, the most common arrangements are square tablets with all four holes threaded, and square tablets with two warp threads in diagonally-opposite holes. Threading two adjacent holes creates possibilities beyond the scope of this article, since any woven structure can be created with tablets threaded this way.

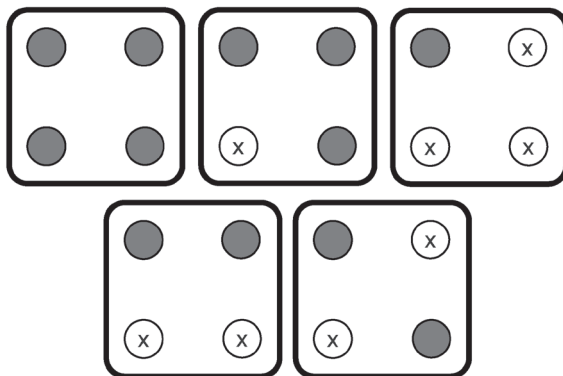


Figure 3.3. Possible ways to thread a square tablet with 4, 3, 2, or 1 warp thread.

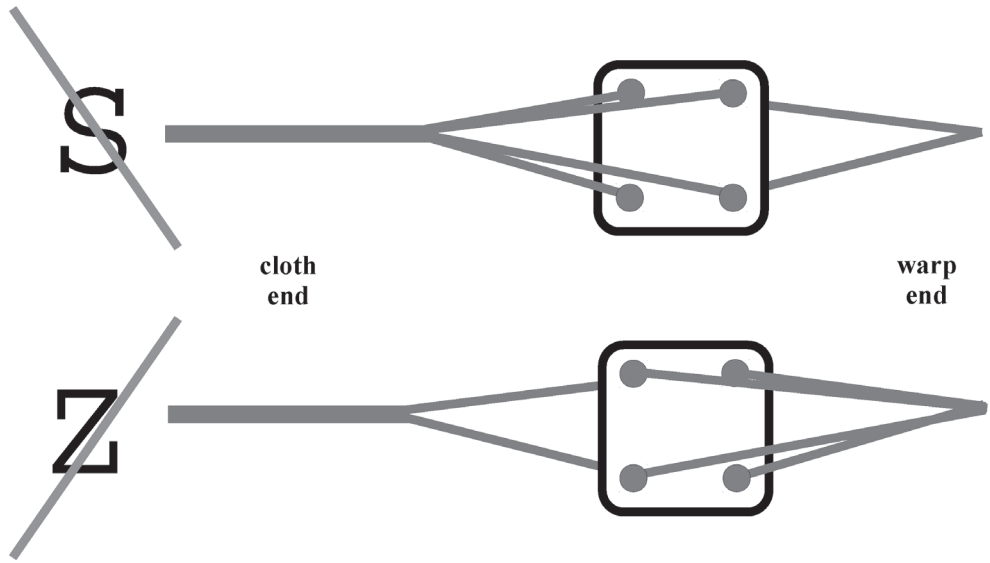


Figure 3.4. **S** and **Z** threading of tablets as seen in the standard position shown in Figure 1. Seen from the top, the warp follows the same direction as the central stroke of an **S** or a **Z**.

Threading Direction

The warp threads enter the tablet on one side and leave on the other, but with a flat tablet there are two possible directions. Using terms borrowed from spinning, one direction is termed **S** and the other **Z** after the directions of their central strokes (Figure 3.4). This is the definition proposed by Collingwood (1996) and used by most weavers and authors, but some authors have chosen to use the opposite definition, or some other terminology entirely, so it is necessary to carefully read any written description of threading direction.

Turning Unit

The way the tablets are warped controls the possibilities of a band, while the turning pattern determines what is actually produced. A tablet can be turned either forward or backward following the definition illustrated in Figure 3.5, and abbreviated as **f** or **b**. Quarter turns are the most common, but half and whole turns can also be used. Eighth turns may be used with square tablets if they stand on their points and on their flats (as in the double shed in Figure 3.2). Sometimes tablets sit idle and are not turned at all.

To create a regularly-repeating structure, each tablet follows a ‘turning unit’, a set of any number of turns in any direction and of any size that moves the tablets, creating a series of new sheds, and finally returns the tablets to their original position (Figure 3.6). The complement of a turning unit swaps the forward and backward turns, and is structurally identical if done with tablets threaded the opposite way, or a mirror image if done with the same tablets. Turning units can be repeated indefinitely. Because of this repetition, **fbfb** is identical to **ffbb** since both will produce the sequence

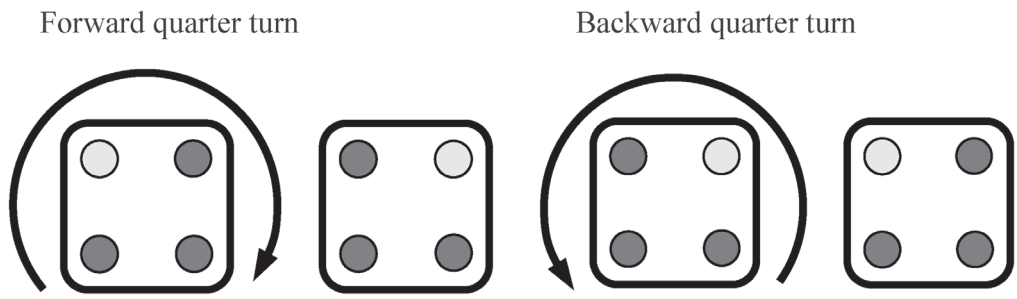


Figure 3.5. Forward and backward quarter turns of a square tablet.

Sequence	Complement	Sequence	Complement
ffff	bbbb	ffF	bbB
fffb	fbff	ffB	bbF
ffbb	bbff	FF	BB
fb	bf	FB	BF

Figure 3.6. Some examples of turning directions and their complements (many more are possible). ‘f’ and ‘b’ denote forward and backward quarter turns, and ‘F’ and ‘B’ indicate half turns. Each set brings a square tablet back to its original position.

ffbbffbbffbbffbb. In practice, bands usually have some interruption in the repeated turning unit, for example to create color patterns in a band.

The turning sequence interacts with the tablet setup to produce the woven structure. There are two major principles governing that interaction. First, in the warp-faced bands produced by tablet weaving, the warp thread that crosses the face of the band when the tablet is turned is the thread that is visible in the band. The lighter gray threads in Figure 3.5 are the ones that will show in the completed weaving after the forward and backward quarter turns illustrated.

The second key principle describes the warp twining that may be produced in a woven band. If a tablet is turned continually in one direction, the four threads from that tablet will twist together into a cord. This cord is bound to adjacent cords (from other tablets in the pack) by the weft. There are other ways to produce warp twining, but its presence in a band, especially in the selvages, strongly suggests that tablet weaving was used. The direction of twist in the cord can also be described as **S** or **Z**. An **S**-threaded tablet turned forward will create a **Z**-twined cord, and an **S**-twined cord if it is turned backward. A **Z**-threaded tablet will produce an **S**-twined cord if turned forward, and a **Z**-twined cord if turned backward (Figure 3.7). Structurally, an **S**-threaded turned forward is identical to a **Z**-threaded tablet turned backward. Tablets are often threaded in blocks of four, following one of three basic threading patterns: **SSSS**, **SSZZ** and **SZSZ**. Swapping **S** and **Z** would give a mirror image, not an entirely different structure.

A single **S**-threaded tablet turned forward repeatedly produces warp twining, with each warp thread following a course like that seen in Figure 3.8. The lower two-thirds

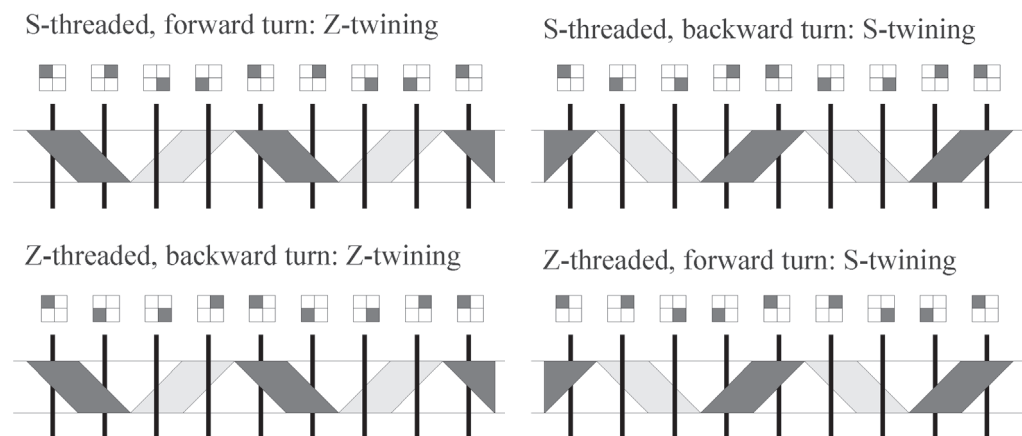


Figure 3.7. The relationship between threading direction (**S** or **Z**), turning direction (**f** or **b**) and warp twining in the resulting cord. Only one hole per tablet is threaded so that the course of the warp on the back of the band (in lighter gray) can be seen.

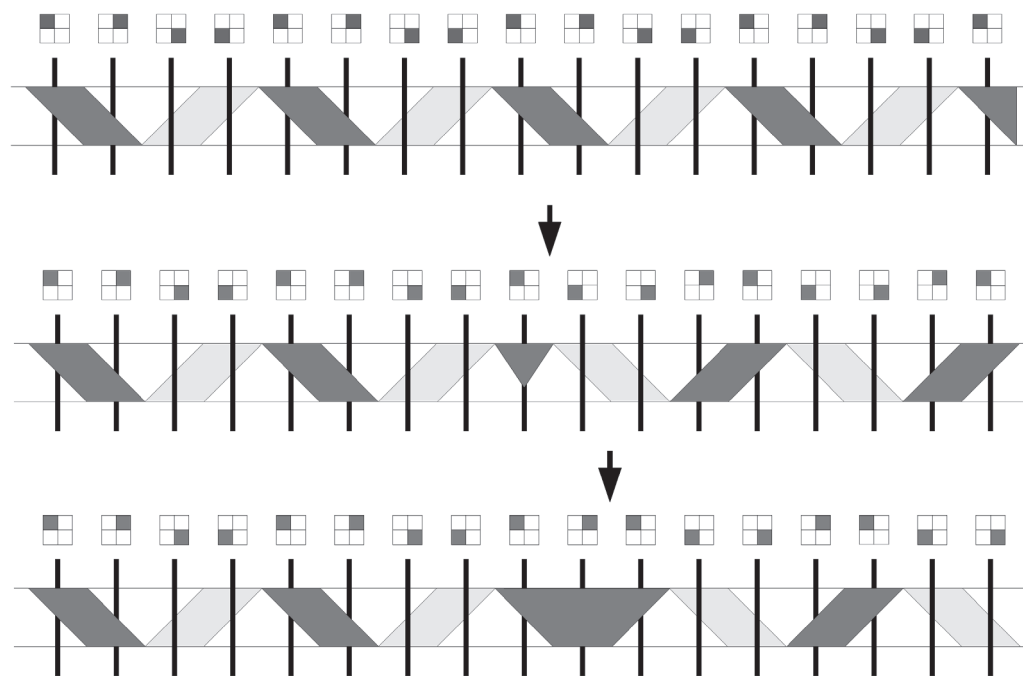


Figure 3.8. Turning sequence **fff** (warp twining) with one warp thread per tablet, without and with reversal points (arrows) that switch the twining direction in the cord.

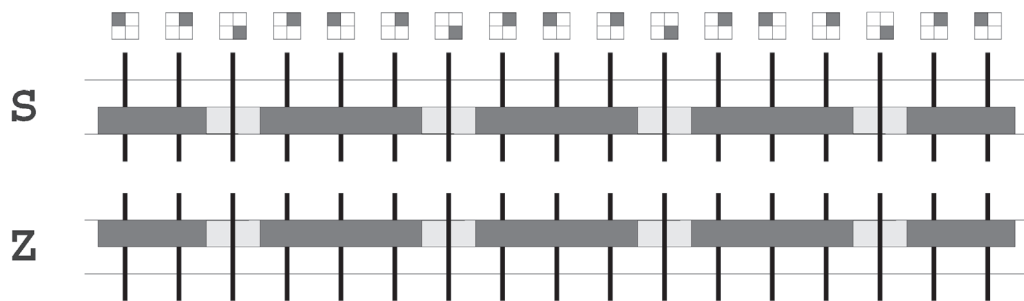


Figure 3.9. Turning sequence **ffbb** with S and Z-threaded tablets with one warp thread.

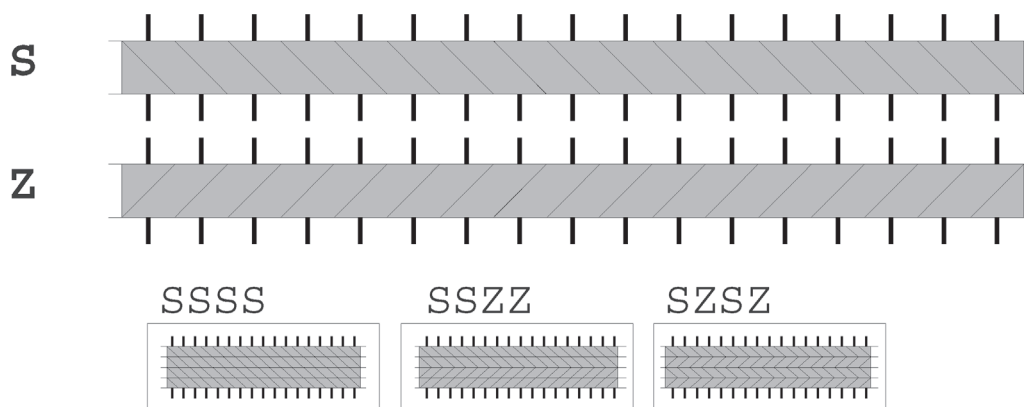


Figure 3.10. Turning sequence **ffff** (warp twining) with four warp threads per tablet, showing a single S- and single Z-threaded tablet, and three sets of four tablets with differing threading directions.

of the figure shows the effect on single warp threads of a reversal at two different points in the turning sequence. Note the change in twining direction following a change from forward to backward turning. Compare the twining at reversals in Figure 3.9, illustrating both S- and Z-threaded tablets turned **ffbb**. There is no warp twining whatsoever; instead, the threading direction determines which side of the band the warp thread occupies.

When a four-warp-threaded tablet is turned **ffff**, each of the threads follows the same course illustrated in Figure 3.8, sequentially appearing on the face of the band and twining around its neighbors while descending to the back (Figure 3.10). The threading arrangement of adjacent tablets determines the appearance of the band. Three common threading arrangements are shown in Figure 3.10. The weft thread does not show, unlike when the turning unit **ffbb** is used (Figure 3.11). As examination of the single warp thread in Figure 3.9 suggests, no warp twining occurs, and the warp thread shows regularly even when all four warp threads are considered. The position of the visible warp depends on the threading of the tablets, giving the **SSSS**, **SSZZ**, and **SZSZ** arrangements distinctive structural differences.

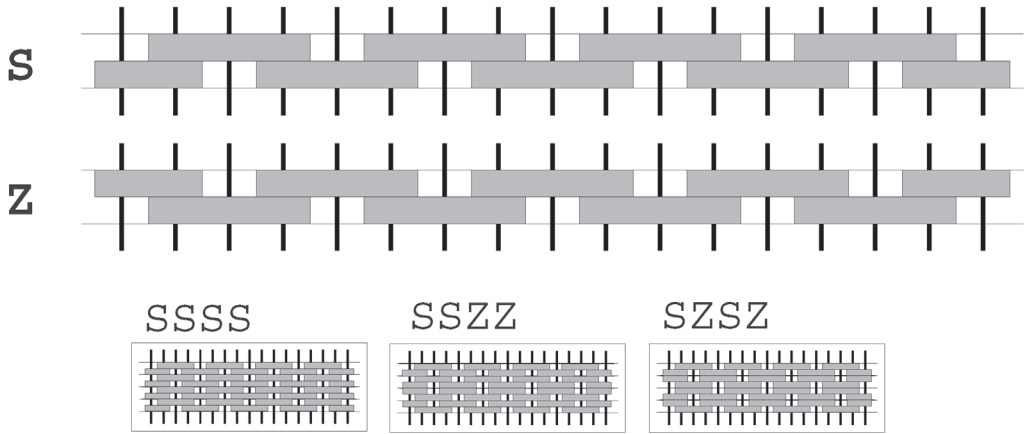


Figure 3.11. Turning sequence **ffb** with four warp threads per tablet, showing a single S- and single Z-threaded tablet, and three sets of four tablets with differing threading directions.

Turning Block

Most tablet-woven bands use at least several tablets, and some use hundreds. Usually all (except perhaps the selvage tablets) are the same shape, and with the same number of holes threaded. All could be threaded and turned identically, but more often adjacent tablets are set up differently to produce a particular structure. The major determinant of structural difference is variation in position within the turning unit.

Tablet weaving structures are often based around regular units of four adjacent tablets. Given a four-element turning unit such as **ffb**, a set of four adjacent tablets could all be in the first position of the turning unit (**1111**), could be one step out of sequence in the first and second positions by pair (**1122**), or alternately out of sequence (**1212**). Tablets can be two steps (a half turn) out of alignment by pairs or alternately: **1133** and **1313**. Three steps out of alignment is effectively the same as one step. Four adjacent tablets can also be in all four possible positions in turn (**1234**). The effects of this alignment are shown in Figure 3.12, a schematic illustration of **ffb** threading with tablets in three different turning blocks: doubleface is **1111**, while **1234** and **4321** produce variants of 3/1 broken twill. This figure introduces a convenient shorthand notation: a forward slash / instead of **f** for a forward turn, and a backward slash \ instead of **b** for a backward turn. In warp-twined structures, an S-threaded tablet turned forward or backward produces a twined band matching the direction of the forward and backward slashes, making them a convenient shorthand for pattern drafting.

Structural Notation

All these traits in combination can be used to describe the production of tablet-woven bands, and thus the corresponding structures, in an unambiguous way. Such an approach allows all the possible methods of production for a given structure to be identified. For notational convenience, shorthand descriptors are combined in the order already used, and assuming knowledge of the tablet shape:

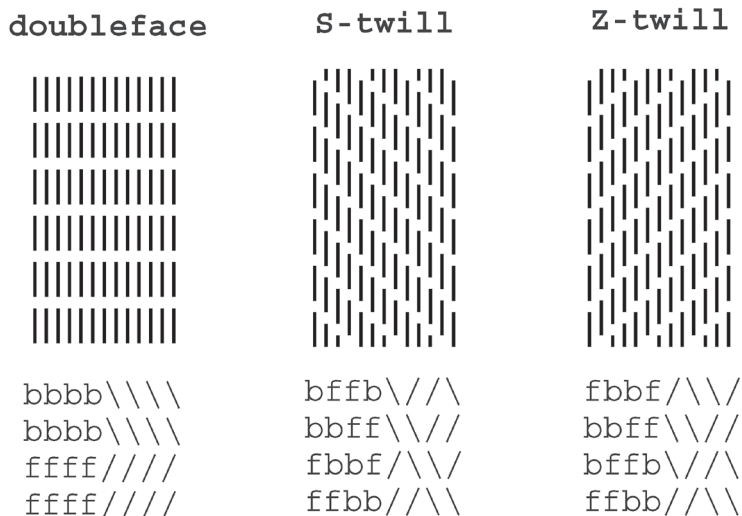


Figure 3.12. Two structures created with turning sequence **ffbb**, including two variants of 3/1 broken twill. Both **f** and **l** are used to denote forward turns, and **b** and **** for backward turns. With vertical diagrams, the warp end is to the top.

1. Number of warp threads per tablet.
2. Placement of those threads in the holes of the tablet (not necessary if all holes are filled).
3. Threading directions (by block, either 4 adjacent tablets or minimum necessary).
4. Turning sequence
5. Starting positions (by block, either 4 adjacent tablets or minimum necessary).

A structure woven on square tablets with all four holes occupied might be described thus: **4-SZSZ-ffff-1111**. This is a warp-twined band with 4 warps per tablet and alternating **S** and **Z** threading.

For square tablets with two warp threads, the description is very similar, but must specify which holes the warps are in. As used here, **A** indicates that the threads are in the cloth/face and warp/back holes initially, and **B** that the warp threads begin in the warp/face and cloth/back holes. **2-AABB-SZSZ-ffbb-1111** is a more complex structure. The first two tablets are threaded through the set of diagonally-opposite holes starting with the cloth/face holes, and the second pair through the other set; the threading is alternately **S** and **Z**; the turning unit is **ffbb**; and the tablets all start in position 1 of the turning sequence.

Standard Structures

Having described in detail the five characteristics of tablet weaving that determine the structure, it is possible to identify the most common values for each trait, and to use those to define standard structures:

- square tablets used on the flat.
- warped with four threads or with two in opposite corners (two possible starting positions). For two-threaded tablets, the starting position matters, so blocks **AAAA**, **AABB**, **ABAB**, **BBBB** can form different structures.
- threaded in blocks of **SSSS**, **SSZZ**, or **SZSZ**.
- turned in repeating units made up of forward and/or backward quarter turns in standard sequences **ffff**, **ffbbb**, **ffbb**, **fb** (as in the first column of Figure 3.6).
- aligned or out of phase in turning blocks: **1111**, **1122**, **1212**, **1234**, **1133**, **1313**.

With four warps for each square tablets, there are one warp setup, three threading sequences, four turning units, and six turning blocks, to produce 72 potential structures. For square tablets threaded with two warps in diagonally-opposite holes, the combination of four warp setups, three threading sequences, four turning units, and six turning blocks produces 288 potential structures. Because of synonymies between certain setups based on the **S-Z** equivalence principle identified above, not all of these combinations produce unique structures. Once duplicates, mirror images and shifts are eliminated, there are 31 unique structures with four-hole tablets and 118 using two-hole tablets. There is no historical documentation for most of these, and many may have never been woven (including, as far as I can tell, any **ffbbb** structure other than my experiments). There are many more potential structures that fall outside this delineation of standard structural components.

Color changes

The interest in many actual tablet-woven bands is provided by color and/or structure changes. While color-arrangement is outside the scope of this discussion, the methods commonly used for color change may also produce structure changes. Even the **ffbb** structures, none of which have twined warps in their basic form, do show twining at the point of color change when woven on tablets. Normally either the turning direction of one or more tablets is reversed, or the tablet is flipped or twisted about its vertical axis and keeps the same turning direction. This takes advantage of the principle that an **S**-threaded tablet turned forward is identical to a **Z**-threaded tablet turned backward and vice versa. Either method produces a longer or shorter float than usual.

Historical Material

Three of the structures woven with four threads per tablet are common enough to warrant more detailed discussion. Rather than provide an exhaustive list of known examples (if that is even possible), I will give an overview of the distribution in time and space for each.

Warp Twining

The classic tablet weaving is warp twining, with tablets turned all in one direction (Figure 3.13). There are only three four-threaded warp twined structures (4-SSSS-ffff-1111; 4-SSZZ-ffff-1111; 4-SZSZ-ffff-1111). Even bands woven in more complex structures frequently have warp-twined selvages. The oldest piece of tablet weaving known to me

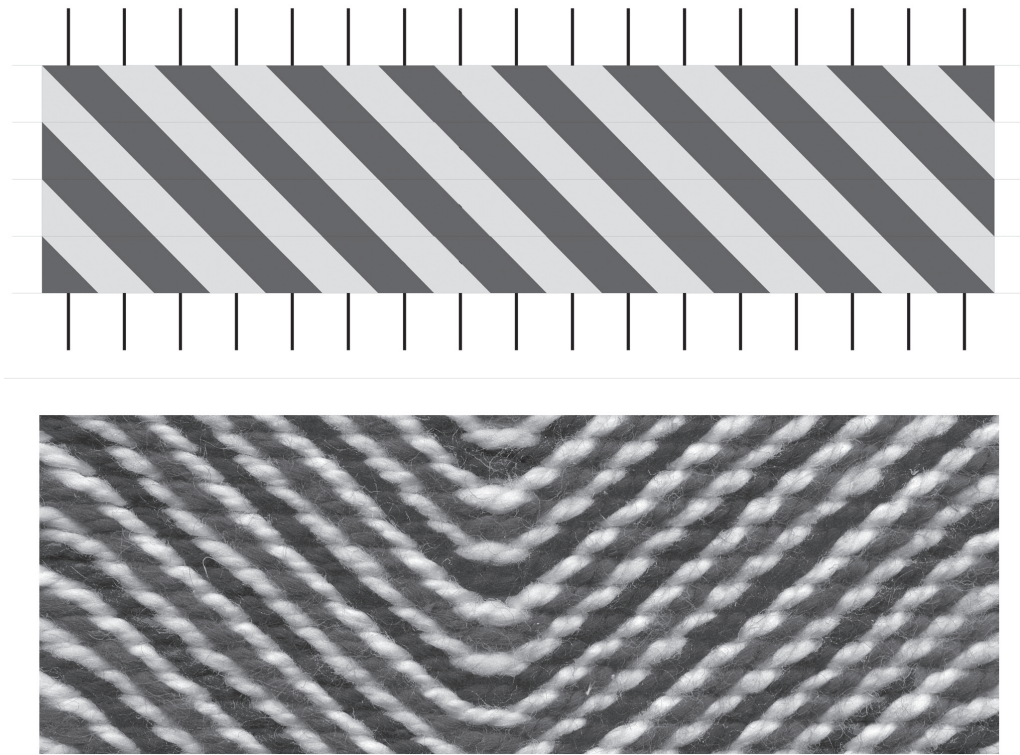


Figure 3.13. Schematic diagram and actual band in **4-SSSS-ffff-1111** warp-twining. The band shows a reversal of all tablets.

is a twist-patterned band from Etruscan Italy, dated to the 9th century BC (Gleba 2007; Knudsen 2007). By far the most common use for warp twining was for starting borders on textiles woven on the warp weighted loom (Collingwood 1996; Hald 1980; Hansen 1990). These borders were very abundant: hundreds have been found on northern European textiles from the 1st century AD until the decline in use of the warp weighted loom. Celtic examples from Austria dated to 8th–4th century BC, and other European bands to 2nd–3rd century AD. Warp-twined starting borders were geographically widespread: examples were known from 4th century BC Spain and 5th century BC Germany (Collingwood 1996). **SSSS** warp twining will twist on itself; **SZSZ** will stay flat, and was the most common kind used for these borders. **SZSZ** warp twining was also known from 6th century AD Egypt (Collingwood 1996; Thomas 1990). Warp twining, primarily **SZSZ**, was the most common ground weave for brocaded bands, also because of the woven band's lack of twist (Henshall 1964; Spies 2000). **SSSS** warp twining was used for applied dress bands in Anglo-Saxon England (Crowfoot 1952), and also making tubular pieces, like several found from 13th–14th century AD England (Henshall 1964; Crowfoot *et al.* 1992). Modern ethnographic examples came from the

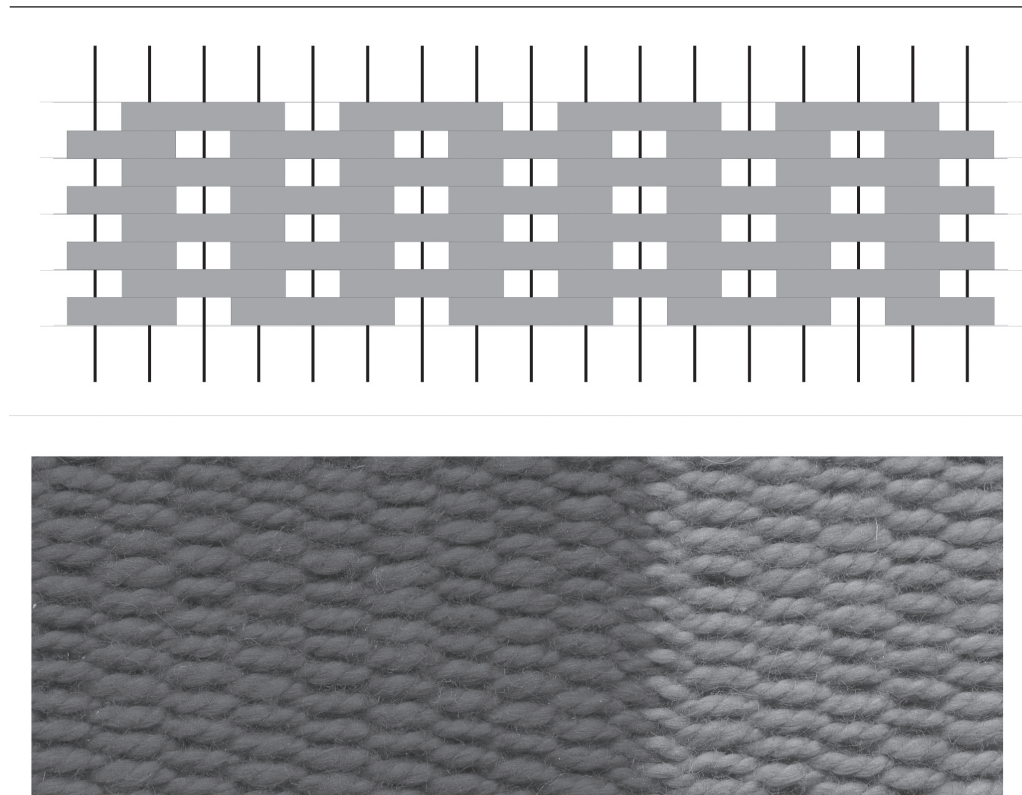


Figure 3.14. Schematic diagram and actual band in 4-SSSS-ffbb-1111 doubleface.

Middle East, Bhutan and Pakistan and from Indonesia (Collingwood 1996). The very common **ffffbbbb** variant was not used widely, if at all, in medieval contexts.

Doubleface

There are ten distinct structures with four threads per tablet and a turning unit of **ffbb**. For the variant called doubleface (4-SSSS-ffbb-1111; 4-SSZZ-ffbb-1111; 4-SZSZ-ffbb-1111), the pack of tablets is turned **ffbb**, making a brick-like pattern with one color always on the face. Colors can be interchanged to form pictures or words. The warp-twining at the color interchange point is dependent on the tablet threading direction, and affects the appearance of the band. The most common doubleface structures are set up with **SSSS** (Figure 3.14) or **SZSZ** (Figure 3.15) threadings; the latter structure loosely resembles knitting. The earliest doubleface known to me is an 8th century AD band with a Greek inscription found at Moscevaja Balka in Central Asia (Ierusalimskaja and Borkopp 1996). Several doubleface bands came from 4th–10th century AD Egypt (Collingwood 1996; Thomas 1990). A late 12th century English seal tag was woven in **SZSZ** doubleface (Henshall 1964). The 17th–18th century AD Gondar tapestries from

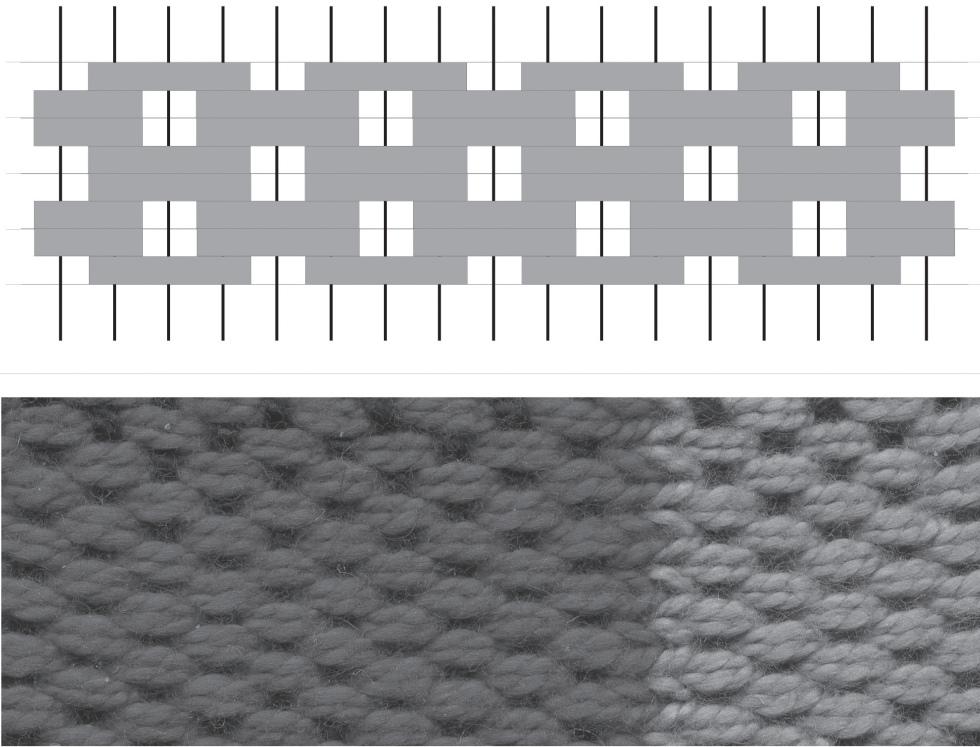


Figure 3.15. Schematic diagram and actual band in 4-SZSZ-ffbb-1111 doubleface.

Ethiopia are remarkably wide. ‘Jerusalem garters’ from the 17th century AD may be European or Israeli, but show a strong European influence (Collingwood 1996; unpublished item in catalog of the Victoria and Albert Museum, London). Doubleface bands of 19th–20th century AD have been collected in Turkey, Uzbekistan, Bhutan, Burma and Indonesia, making this one of the most widespread structures (Collingwood 1996; van Epen 1996; unpublished item in catalog of the Victoria and Albert Museum, London).

3/1 Broken Twill

When weaving 3/1/ broken twill, tablets are turned **ffbb** as for doubleface, but in a staggered sequence (**1234**) so instead of a brick-like pattern a diagonal ridge or wale is formed (4-SSSS-ffbb-1234; Figure 3.16). Color changes are done as for doubleface, but in such a way as to preserve a smooth diagonal boundary. The earliest patterned twill bands were found in the 3th–4th century BC Celtic burial in Austria (Gromer 2005). An unpatterned twill band came from 3th–4th century AD Poland (Collingwood 1996). Patterned twill was known in Viking Scandinavia, with examples from Sweden and

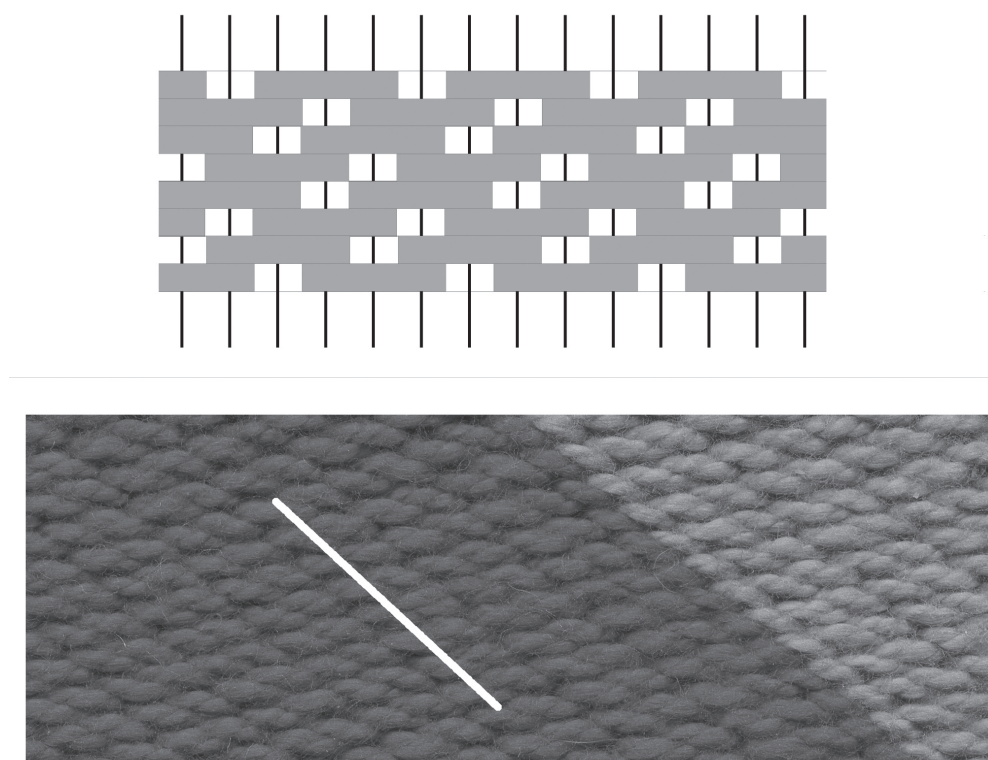


Figure 3.16. Schematic diagram and actual band in **4-SSSS-ffbb-1234** 3/1 broken twill. The white line indicates the twill direction.

Norway (Collingwood 1996; Hansen 1990). An impressively complex band from Birka had brocading over a patterned twill ground weave (Geijer 1980), as did a 10th century AD band from Durham, England (Crowfoot 1939) and a 12th century AD Sicilian band (Collingwood 1996). Other English and Central European examples of 3/1 twill dated from the 10th–14th century AD (Henshall 1964; Collingwood 1996; Crowfoot *et al.* 1992).

Tablets with Two Warp Threads

The second most common setup for tablet weaving uses square tablets threaded in either adjacent or diagonally-opposite holes. This setup can produce a wider range of structures than threading all four holes because of the increased complexity created by the ability to offset the holes threaded. Warp-twining with staggered diagonally-threaded tablets was used in 4th–6th century AD Scandinavia (Collingwood 1996; Hald 1980; Nockert and Knudsen 1996). A Bronze Age tabby woven on tablets was found in Denmark (key indicator: warp-twined selvages). Tabby bands from the 6th and 14th century AD were found in England (Crowfoot 1956; Crowfoot *et al.* 1992). The earlier

one was woven in a color patterning method that showed tabby on the face but long floats on the reverse (Crowfoot 1954). The most elaborate two-hole weave may be the Hochdorf pebble weave, named for the 6th century BC German site from which several elaborate examples came (Bank-Burgess 1999; Knudsen 1994). A later example of this weave came from 7th–8th century AD France (van Epen 1997).

Surface Treatment

Brocading

Brocading with an extra decorative weft was known from the 6th century AD onward and possibly beginning in northern Europe and spreading south. Brocading was usually applied to **SZSZ** warp-twined bands (Spies 2000). Brocaded bands were very widespread in both space and time, from Viking Scandinavia (notably Birka, Sweden; Geijer 1980, including an example on 3/1 broken twill) and Anglo-Saxon England (Crowfoot 1952), all over central Europe and England in the 11th–14th century AD (Müller-Christensen 1977), and in Albania into the 19th century AD (unpublished item in catalog of the Victoria and Albert Museum, London).

Soumak

Surface wrapping with decorative weft, or soumak, was known from Northern Europe, 5th–7th century AD (Collingwood 1996).

Velvet

Tablet-woven velvet, the use of warp pile on tablet-woven bands, was known from one medieval Italian example (woven on eight-hole tablets), and several Uzbek examples from 19th–20th century AD (Collingwood 1996).

Other Tablet Shapes

Triangular Tablets

Three-sided tablets have been found in Roman sites in England, but no three-holed band has yet turned up (Collingwood 1996).

Square Tablets

In addition to the structures already described in detail, many other types of bands woven on square tablets were known. A four-color patterned weave often termed ‘Snartemo’ from the Norwegian find from which it was most well-known, and which used **ffff** for the ground weave and **fbf** for patterning, has been found at other Scandinavian sites (6th–10th century; Collingwood 1996; Englund 1994; Hansen 1990; Nockert 1983). Diagonal patterns based on intermixed **ffff** and **bbbb** turning units (called Egyptian but not) were known from Finnish finds (10th–11th century; Collingwood 1996; Hansen 1990).

Hexagonal Tablets

Six-sided tablets sometimes appeared in medieval artwork, often employed by the Virgin Mary, but few bands woven on these tablets have survived (Collingwood 1996; Spies 2000). A 14th century AD band from Hull, England used six-sided tablets to produce two sheds (Walton 1987).

Octagonal Tablets

Eight-sided tablets were known from medieval artwork, and from three surviving bands: the Dune belt, the belt of Eric of Pomerania (13th–14th century AD Sweden) and a 15th century AD Italian velvet band (Collingwood 1996; Holmqvist 2010 and this volume). The first two use both eight-thread warp twining and a complex pattern with four of the eight holes threaded.

Conclusions

The earliest known tablet-woven band is a single color twist-patterned piece from 9th century BC Italy. Other very early bands came from Greece and Spain, suggesting a southern European origin for this craft, but that is really just speculation without more data. By the time of the European Celtic burials (8th–4th century BC) very elaborate structure and patterning were known, using both two- and four-holed tablets.

Tablet weaving reached its height during Anglo-Saxon and Viking-Era northern Europe. Warp-twined starting borders were a key component of weaving on a warp weighted loom. Bands in many structures have been found, and bands decorated with soumak or metallic brocade were common. Tablet weaving persisted until at least the late Middle Ages. The sporadic presence of very complex structures like that used in the Eric of Pomerania belt hint at a wider distribution of those techniques. While basic warp-twining was widespread and commonly practiced, these complex patterns would require a skilled and experienced weaver.

Trade throughout northern and central Europe can explain the diffusion of techniques, but what about its wider distribution? Tablet weaving both simple and elaborate has been found in the Middle East, Indonesia, Central Asia and the Indian subcontinent in the 19th–20th century AD. Given currently-available data, it is impossible to say how tablet weaving got there, or when, although speculation is endlessly fascinating.

Tablet-woven structures can be described completely and unambiguously using five criteria describing the warp set-up and the weaving procedure:

1. Number of warp threads per tablet.
2. Placement of those threads in the holes of the tablet.
3. Turning sequence of an individual tablet.
4. Starting positions (by block, either 4 adjacent tablets or minimum necessary).
5. Threading directions (by block, either 4 adjacent tablets or minimum necessary).

A systematic analysis of basic structures using limited combinations of the above criteria reveal that even if duplicates and mirror images are removed, there are large numbers of possible structures (31 using four-hole, and 118 with two-hole tablets), and if color patterns are included the possible arrangements are nearly overwhelming. Although these include only a subset of the available combinations, this level of complexity is not expressed in either documentable historic or modern tablet weaving. The classification described here provides a framework for analysis of existing bands and a source of inspiration for development of new tablet-woven structures.

References

- Banck-Burgess, J. (1999) *Hochdorf IV: Die Textilfunde*. Stuttgart, Konrad Theiss.
- Collingwood, P. (1996) *The Techniques of Tablet Weaving*. Second edition. McMinnville, Robin and Russ Handweavers.
- Crowfoot, E., Pritchard, F. and Staniland, K. (1992) *Textiles and Clothing c. 1150–c. 1450. Medieval Finds from Excavations in London: 4*. London, HMSO.
- Crowfoot, G. M. (1939) The tabletwoven braids from the vestments of St. Cuthbert at Durham. *Antiquaries Journal* 19, 57–80.
- Crowfoot, G. M. (1952) Anglo-Saxon tablet weaving. *Antiquaries Journal* 32, 189–191.
- Crowfoot, G. M. (1954) Tablet woven braid from a thirteenth century site. *Antiquaries Journal* 34, 234–235.
- Crowfoot, G. M. (1956) The textile and impressions. In Thompson, F. H. *Anglo-Saxon Sites in Lincolnshire*, 188–189. *Antiquaries Journal* 36, 181–199.
- Englund, S. B. (1994) *Brickvävning Så in i Norden*. Kalmar.
- Geijer, A. (1980) The textile finds from Birka. *Acta Archaeologica* 50, 209–222.
- Gleba, M. (2007) Textile production in Proto-historic Italy: from Specialists to Workshops. In Gillis, C. and Nosch, M.-L. *Ancient Textiles: Production, Craft and Society*, 71–76. Oxford, Oxbow Books.
- Gromer, K. (2005) Tablet-woven ribbons from the prehistoric salt-mines at Hallstatt, Austria – results of some experiments. In Bichler, P. et al. (eds) *Hallstatt Textiles*, 81–91. BAR International Series 1351.
- Hald, M. (1980) *Ancient Danish Textiles from Bogs and Burials: A Comparative Study of Costume and Iron Age Textiles*. Copenhagen, National Museum of Denmark.
- Hansen, E. (1990) *Tablet Weaving: History, Techniques, Colors, Patterns*. Denmark, Hovedland Publishers.
- Henshall, A. (1964) Five tablet-woven seal tags. *Archaeological Journal* 121, 154–162.
- Holmqvist, V. (2010) A Study of Two Medieval Silk Girdles: The so-called ‘Eric of Pomerania’s Belt’ and the Dune Belt. In Andersson Strand, E. B., Gleba, M., Mannering, U., Munkholt, C. and Ringgard, M. (eds) *North European Symposium for Archaeological Textiles X*. Oxford, Oxbow Books.
- Ierusalimskaja, A. A. and Borkopp, B. (1996) *von China nach Byzanz*. Munchen, Herausgegeben vom Bayerischen Nationalmuseum und der Staatlichen Ermitage.
- Knudsen, L. R. (1994) Analysis and reconstruction of two tabletwoven bands from the celtic burial hochdorf. In Jaacks, G. and Tidow, K. *Northern European Symposium on Archaeological Textiles Volume 5*, 53–60. Textilmuseum Neumuster.
- Knudsen, L. R. (2007) ‘Translating’ archaeological textiles. In Gillis, C. and Nosch, M. B. *Ancient Textiles: Production, Craft and Society*, 103–111. Oxford, Oxbow Books.
- Müller-Christensen, S (1977) Examples of mediaeval tabletwoven bands. In Gervers, V. (ed.) *Studies in Textile History in Memory of Harold B. Burnham*, 232–236. Toronto, Royal Ontario Museum.
- Nockert, M. (1983) A Scandinavian haberget? In Harte, N. B. and Ponting, K. G. (eds) *Cloth and Clothing in Medieval Europe: Essays in Memory of Professor E. M. Carus-Wilson*. Studies in Textile History 2, 100–107. London, Heinemann Educational Books.
- Nockert, M. and Knudsen, L. R. (1996) Gotlandska brickband fran vikingatiden. *Gotlandskt Arkiv* 68, 41–46.
- Spies, N. (2000) *Ecclesiastical Pomp and Aristocratic Circumstance: A Thousand Years of Brocaded Tablet woven Bands*. Maryland, Arelate Studio.
- Thomas, T. K. (1990) *Textiles from Medieval Egypt, AD 300–1300*. New York, Carnegie Museum of Natural History.

van Epen, M. (1996) *Special Tablet Weaves*. Netherlands, De Kaart.

van Epen, M. (1997) Tablet weaving- two threads per tablet. *TWIST* 4(3), 8.

Walton, P. (1987) Textiles and caulking cords. In Armstrong, P. and Ayers, B. Excavations in High Street and Blackfriargate. *East Riding Archaeologist* 8, 227–232. Hull Old Town Report Series 5.

The Use of Craft Skills in Historical Textile Research: some examples drawn from a study of Medieval tablet weaving

Viktoria Holmqvist

Skill-based knowledge ought to play an important part when researching historical textiles and their production. In experimental archaeology, the use of traditional crafts is widespread. However, the emphasis put on repeatable and controllable experiments becomes problematic if the part craft skills play is not fully recognised. Since craft skills are intimately connected to the performance of the individual craftsperson, they may not always be suitable as a basis for broad generalisations about past activities and practices. They need to be assessed in relation to the archaeological and historical record and subjected to the same critical evaluation as any other source used in academic research. Bearing this in mind, crafts and the practical knowledge they contain are invaluable when working with historical textiles. The author presents the working method used to analyse two medieval silk girdles as an example of this and demonstrates how practical craft skills can be used to further question and investigate the sources available to the textile historian.

Introduction

In archaeology, a discipline that by its very nature moves back and forth between the natural sciences, the social sciences and the humanities, what constitutes a scientific approach can vary greatly depending on the background and training of the archaeologist. To this mix of different academic traditions, we may also add the practical knowledge and skills originating from craft practices, which are often included in experimental archaeology. Being a handweaver and practising craftsperson as well as an academic specialising in archaeological textiles, the author finds this combination of perspectives particularly interesting and continually tries to explore the possibilities it offers in a research situation.

Nevertheless, drawing conclusions about the past from what people do today is problematic. On the one hand, there is the temptation to make too simple analogies

with present-day craft practices. On the other hand, there is the pitfall of ignoring useful input simply because the source is a modern practice. Most people working with crafts today have their own preferred way of doing things, which may be very different from any other craftsman, past *or* present. Also, they do not necessarily practise ancient techniques in the same way, with the same type of tools or for the same reasons as, for example, a medieval craftsman (compare with Andersson Strand 2010, 2). But together with critical discussion, evaluation and comparisons – just as in any research – craft skills can provide new and important knowledge to the study of historical textiles. However, it is important not to shy away from the complexity of crafts in a research context, or to try to simplify them by failing to recognise the uncertainties they contain.

The first part of this article will touch very briefly on a few theoretical and methodological considerations concerning practice, practical knowledge and traditional scholarly research. The second part will then outline a way of working with both theoretical and practical perspectives in a fairly traditional study of historical textiles. For this, the author's own work with the medieval silk girdle commonly known as Eric of Pomerania's Belt shall be used as an example (the results of that particular study can be found in Holmqvist 2010). An attempt shall also be made to take the discussion one step further by examining some questions that were raised during the reproduction of the unusual weave structure of Eric of Pomerania's Belt. The answers to these could be found by turning to other historical sources and evaluating them from a craftsman's point of view.

The silence of practical knowledge, experimental archaeology and the nature of crafts

The idea of two different kinds of knowledge – theoretical/intellectual on the one hand and practical/skill-based on the other – derives from the ancient Greek philosophers and their view that science was a purely intellectual pursuit and that practical knowledge did not constitute science (see for example Molander 2003, 59). Needless to say, quite a lot has been written on the subject since then. In the past fifty years or so, people working mainly in the fields of philosophy, social sciences, information sciences, art and design have spent a lot of effort on defining and re-defining knowledge to either bridge or to emphasise the divide between 'theory' and 'practice'.

Practical knowledge has been defined variously as *tacit knowing* (Polanyi 1983), *unarticulated knowledge, rules-of-thumb* (Franssen *et al.*), *action-mediated knowledge* (Narmo 2010) and *knowing-in-action* (Schön 1983). These different terms are not necessarily interchangeable, but they are all meant, in one way or another, to capture the idea that there is a 'silent knowledge' that skillful individuals express by performing an action, as opposed to knowledge that is formalised and written down. This personal 'knowing-how' can take as diverse forms as the ability to recognise a face, riding a bike (Polanyi 1983, 4–5; 1962, 49) or, slightly more relevant to this article, the embodied skill of a practitioner who plies his or her craft (Schön 1983, viii–ix; Polanyi 1962, 53). This type of unexpressed knowledge can be seen as problematic in a scientific context – it is personal, subjective and does not easily submit to standard scientific testing and rigour. But craft skills are what produced most of the artefacts that an academic discipline such

as archaeology studies and the practical knowledge of historical crafts needs to have a place among the bones, potsherds and textile fragments.

Using crafts in archaeological research is of course nothing new and there are several definitions and discussions of experimental archaeology (see for example Coles 1979; Reynolds 1999, 127–129; Mathieu 2002; Cunningham *et al.* 2008, Narmo 2010). Most of these emphasise the importance of controllable and repeatable experiments and the subsequent dissemination of results. They are also careful to separate ‘activities’ (like demonstrating historical crafts) and ‘experience’ from true experiments, which adhere to the scientific principles of hypothesis testing and validation. However, the part of crafts that is ‘silent’, that hard-to-define component that is made up of the practitioner’s skill, familiarity with techniques and materials, experience, reflection, tradition and creativity is difficult to properly account for in an experimental situation. Several of the definitions of experimental archaeology do not concern themselves with the actual *practical* skills that are necessary to carry out the experiments; they only outline the *theoretical* framework, present a standard methodology and add a few common scientific criteria (for example Reynolds 1999; Mathieu 2002). Is the ability to perform the sometimes quite demanding practical tasks within the experiment taken for granted or are the researchers supposed to learn the necessary skills as they go along? Either way, the problem is that becoming a skilled craftsperson takes years and years of practice and while acquiring the necessary skills, or adapting already existing ones to suit a different context, may be a part of the experiment, it seems to be left out of the discussions most of the time despite being such an important variable. There are of course exceptions. In the case of Cunningham *et al.* (2008), the importance of involving craft experts in the experiments is indeed mentioned, although it is not expressly included in the concise definition of experimental archaeology given (Cunningham *et al.* 2008, v). Hansen highlights the problem of the researcher-gone-craftsperson and the possible conflicts of interests this combination presents (Hansen 2008, 70–72). One solution offered by her is the increased and long-term cooperation between craft practitioners, experts and the archaeologists conducting the experiments (Hansen 2008, 73). Another example that recognises practical skills is the guidelines for experimental textile work laid down by the research programme *Textile and Tools – Texts and Contexts* at the Centre for Textile Research, Copenhagen. These include the statement that “[e]ach test is to be performed by at least two skilled craftspeople” (Andersson Strand 2010, 2). In her article about her work with the tablet-woven bands from the Kirkkomäki burial ground in Finland, Silja Penna-Haverinen comes to the conclusion that “[e]xperimental archaeology is, indeed, vitally dependent on the researchers’ own skills as craftspeople and as scholars” (Penna-Haverinen 2010, 200). She carefully reflects on both her own skills and on the choices she made during the reconstruction of the bands and presents this along with the results of the experiments.

If we believe that craft skills are important factors in an archaeological experiment, their role ought to be defined along with the other component parts that make up experimental archaeology. It is also important for practitioners and non-practitioners alike to seriously consider the nature of crafts – that, since the skill is intimately connected to the individual practitioner, there may not be a one-to-one correspondence between process and result, how something is done and the finished object. In crafts,

there are multiple ways to achieve the same results and the process or even the tools of one craftsperson may not be the same as those of another. These discrepancies of practice are next to impossible to control and will inevitably affect the result of an experiment. It will do so *whether it is acknowledged or not*. However, crafts are by no means unique in that they rely on skilled practitioners. Even natural scientists use a considerable amount of practical knowledge and skills in their research when they collect samples, mix chemicals or study cells through a microscope. Citing the work of sociologist Bruno Latour, textile archaeologist Lise Bender Jørgensen argues that “[w]hen science is perceived as a *practice* the similarities to other practices, and practical knowledge, becomes [sic] obvious, and the dichotomy of theory and practice begins crumbling. If data are seen as the raw materials of the scientist, theories and methods may be termed his or her tools, and the wording of an argument and the referencing of its empirical foundations may be seen as work processes that require considerable skill” (Bender Jørgensen 2007, 9).

Working to include the practical knowledge contained in crafts into an academic context is worth the effort. Crafts in experiments may need to be evaluated with greater care and the uncertainties they contain must be recognised. Some definitions of experimental archaeology emphasise the importance of relating the results back to the archaeological material (Cunningham *et al.* 2008, v; Reynolds 1999, 127, see also Penna-Haverinen 2010, 199–200). Furthermore it can be argued that the actual craft performance or practice also needs to be clearly related to the archaeological material – and perhaps to other available sources, too – if work is to be relevant in a historical context.

Analysing archaeological textiles with the help of craft skills – a practical example

The author first began working with the medieval silk girdle commonly known as Eric of Pomerania’s Belt, as part of a bachelor’s thesis in Textile Sciences and Handweaving at the University of Borås, Sweden. Because of the scope of the work, after the degree was awarded the study was developed further and the final results were presented at the tenth NESAT conference in Copenhagen in 2008. The requirements of the thesis meant that the work process itself had to be documented and evaluated along with the results. The bachelor’s project partly became a methodological investigation to see what weaving as a craft could add to a ‘standard’ analysis of a medieval textile. It also became a point of departure that allowed exploration of how craft skills are employed in an academic context.

Eric of Pomerania’s Belt

Eric of Pomerania’s Belt is an exceptionally well-preserved silk girdle kept at the National Museum in Copenhagen, Denmark. At the time that the study began, not a lot had been written about the belt and no complete analysis of the weaving technique existed: it appears that Poul Nørlund’s article from 1937 (Nørlund 1937) and a brief description in Ilse Fingerlin’s *Gürtel des hohen und später Mittelalters* (1971), along with a short text in an exhibition catalogue (*Unionsdrottningen* 1996, 386), were all that had been published. The belt itself has been dated to somewhere between the early 13th century and the middle of the 14th century, while the buckle and strap-end are of a

later date, around the middle of the 15th century (Nørlund 1937, 322–323; Fingerlin 1971, 52). Although Nørlund attempts a cursory description of the weave, he leaves the question of *how* the girdle was made – whether it was tablet-woven or not – fairly open: it *might* be tablet-woven, he suggests, but since it lacks warp-twining, which is the usual distinguishing feature of that technique, that is not very likely (Nørlund 1937:318). For a more thorough discussion of the belt and its history, see Holmqvist (2010) and Nørlund (1937).

The aim of the thesis was to find out exactly what the weave structure of Eric of Pomerania's Belt was, and to give a definite answer as to whether it was tablet-woven or not. Being an accomplished and enthusiastic tablet weaver, as well as an ordinary weaver, the author had the skills to not only recognise the different weave structures, but also to reproduce them if necessary. However, because of this craftsperson's bias towards tablet weaving, it was particularly important that the study was conducted with an open and questioning mind to avoid jumping to conclusions concerning the weaving technique.

The following was written about the work process when analysing the belt: "Studying literature and other people's research offers a preliminary understanding of Eric of Pomerania's Belt and its place in history; information which might help when doing the analysis of the actual girdle. Trying to reproduce the weave might in turn raise new questions about the analysis, the girdle and previous research. By continually going back and forth between these different aspects of my work, I hope to find a productive combination of theory and practice that my study of Eric of Pomerania's Belt will benefit from." (Holmqvist 2007).

This cyclical way of working obviously shares many characteristics with the idea of Hermeneutic interpretation and the view that the understanding of the whole is related to the understanding of the individual parts, and *vice versa*. It also bears a resemblance to Donald A. Schön's description of the process of designing as a 'conversation with the materials of a situation' (Schön 1983, 78). Thinking about the work as a dialogue helped to conduct the study of Eric of Pomerania's Belt in a reflective way. The 'materials of the situation' were listened to, the author's input added and attention was then paid to how they responded. This ensured that the study did not fail to question the results or relate them to previous research and to the primary material – the medieval girdle itself.

When it comes to the study of archaeological textiles, a technical analysis is a well-established way to begin the scientific description of a textile. That means identifying the fibres, recording spin direction and spin/twist angle of the thread and determining weave structure and thread count. This is where the study of Eric of Pomerania's Belt began too. The initial technical analysis of the weave structure was carried out with a hand-lens at the National Museum, Copenhagen, and continued at home with the help of high-resolution close-up photographs taken at the museum. Later, the belt was studied through a stereoscope at the museum. The results mainly confirmed Nørlund's findings: The belt is woven with slightly S-twisted silk threads in blue, green and a much faded red. It is a two-layered warp-patterned double weave based on a 2/1 twill, with a supplementary pattern weft of gilt silver on both sides of the belt. There is no observable warp-twining in the weave that would indicate that it is tablet-woven, but

tablet weaving would be an appropriate technique for producing the complicated and varied patterns. The patterns are mirrored on the back of the belt in such a way that the warp threads appear to work in pairs, as is common in a double weave: green pattern elements are always blue on the other side, while red pattern elements are red.

While finishing the analysis, a search was made for comparative material. There were two other medieval belts that were mentioned in connection with Eric of Pomerania's Belt (Fingerlin 1971, 52–53; Nørlund 1937, 322): one from Hungary which was only sketchily described, and – more interestingly – some woven belt fragments from the so-called Dune treasure hoard from Gotland – the largest medieval gold and silver treasure ever found in Sweden, now on display in the Golden Room of The National Museum of Antiquities, Stockholm. In the museum's online collection database, the Dune Belt was described as tablet-woven so it was thought that it would be an interesting comparison as neither Nørlund's technical analysis nor that of this study had been able to rule out that technique completely in conjunction with Eric of Pomerania's Belt. The decision was made to include the Dune Belt in the study.

When studying the Dune Belt under the microscope, it was discovered with amazement that while the edges certainly had the characteristic warp-twining of a tablet-woven band, the patterned part in the middles had the *exact* same apparently non-twining weave structure as Eric of Pomerania's Belt. The only difference was that the Dune Belt lacked the supplementary pattern weft and seemed to have a slightly simpler pattern than Eric of Pomerania's Belt. This suddenly made it much more likely that Eric of Pomerania's Belt might be tablet woven after all. But the appearance of neither belt corresponded to any tablet-weaving technique the author had ever seen, nor could anything like it be found anywhere in what had been published on tablet weaving or in the archaeological record.

Based on the analysis and comparisons with the Dune Belt, the following tentative conclusion was drawn about Eric of Pomerania's Belt:

- Eric of Pomerania's Belt is possibly tablet-woven, but without warp twining

If the study had been a purely academic endeavour, like most analyses of archaeological textiles are, it would have ended here. Any uncertainties or mistakes would have remained unresolved and little new knowledge would have been gained about Eric of Pomerania's Belt, except for a slightly more detailed description of the belt's appearance and its closer connection to the woven belt fragments from the Dune find. But the next step was now to test the results of the study in practice – to see if it was actually possible to weave something based on the findings.

Using the discoveries about Eric of Pomerania's Belt so far, an attempt was made to reproduce the weave with tablets, but without warp-twining. It is perfectly possible, although perhaps not optimal, to reproduce an ordinary interlaced weave structure with tablets, as weaver Peter Collingwood points out in *The Techniques of Tablet Weaving* (Collingwood 1996, 167). For the first weaving sample weaving tablets were used as shedding devices to make the threads work in pairs according to the principle Collingwood describes (1996, 155–156). It seemed to work very well and on the surface produced a band that appeared identical to Eric of Pomerania's Belt. It was not until this replica was compared with the actual original that it was noticed that the tiniest of details

on the reverse side of the new sample did not match the medieval belt: The stitching or binding thread that connects the two layers of the double weave was in a different place on the back of the band. Since this thread takes up less than one millimetre of space in the weave, and only makes a short float over one weft and is partially hidden beneath the 2/1 twill, it had not been noticed before. What actually happens in Eric of Pomerania's Belt is that when a warp thread moves from one layer of the double weave to the other, it shifts its position sideways, actually *crossing* some of the other threads. The effect it has on the overall appearance of the weave is so subtle that it is almost invisible, but this sideways shifting of threads means that Eric of Pomerania's Belt definitely *is* tablet-woven – the shift is the result of warp twining.

So after weaving a sample, that is, subjecting the tentative conclusion to a practical test, it was proven wrong:

- Eric of Pomerania's Belt is ~~possibly tablet-woven, but without warp twining~~ tablet-woven, with warp twining

The new result, taken together with the warp twining of the Dune Belt edges (which actually merited another detailed study and several weaving samples of their own), eventually enabled the reconstruction of the previously undocumented tablet-weaving technique used for both Eric of Pomerania's Belt and the Dune Belt fragments with octagonal weaving tablets and four warp threads in each tablet (see Holmqvist 2010 for a description of this and also a discussion on possible alternatives).

The standard methods of analysing historical textiles are in fact practices; they are part of the textile archaeologist's craft of reducing the world to a manageable, researchable scientific format (compare with Latour 1999). Like most practices, they are not infallible, something which analysing really complex weave structures demonstrates. The technical analysis of a piece of fabric may look correct and convincing on paper, like this study's first analysis of Eric of Pomerania's Belt. But woven threads move in three dimensions and sometimes it is difficult to see what they actually do, even under a microscope. As the complexity of the weave increases, so do the opportunities for mistakes to find their way into the analysis. A weave structure is usually represented by a two-dimensional drawing, and the loss of the third dimension makes any mistakes much less noticeable. This is where the skill of weaving becomes an invaluable research tool as it can be used to test the results of an analysis.

Taking it further

Using weaving to test results satisfies the demands of formal experimental archaeology. But weaving a complex patterned weave like that of Eric of Pomerania's Belt naturally involves much more than just the confirmation of a result. Mathieu and Meyer observe that experimentation can generate an appreciation for what a particular activity involves and that the experimental process inspires inferences about materials, tools and techniques among other things (Mathieu and Meyer 2002, 75). They state that 'experimentation can be seen as *an engine of hypothesis generation*, not just for further experimentation, but also for *other means of archaeological testing*' (Mathieu and Meyer 2002, 75, original emphasis).

Trying out the reconstructed weaving technique of Eric of Pomerania's Belt gave rise to some questions concerning the set up of the warp. Like most modern weavers would, the replica band was worked in front of the weaver, with the right side facing up and the other facing down. The tablets hung on the warp with no support. While the technique itself worked perfectly, there were a few practical problems. After each turn of the tablets, the weaver needs to check that the sheds for the double weave were clear before passing the weft. The high thread count (over 110 threads/cm, see Holmqvist 2010) and the relatively small sheds made this necessary to avoid mistakes that would ruin the pattern. But with the warp set up in the usual way, to do this the weaver has to bend down and look into the sheds from the side, which was time-consuming and did not provide a good enough view. The slightly unbalanced tablets – a result of having only four out of eight holes threaded – added to the problem of unclear sheds as the tablets tended to slip out of position. Also when access to the back of the band was needed, to add the supplementary brocading weft, turning the entire weaving 180 degrees was both difficult and threatened to ruin the weaving. This inspired a search for a different way to set up the warp, preferably one that could be related to a historical context.

Medieval band weaving looms

There are several medieval manuscript illuminations that show what can only be assumed to be tablet weaving. These images depict a simple kind of band loom or weaving frame. However, using medieval art as a source for real-life objects and activities is a difficult undertaking. It has been put forward by art historians that medieval art is mostly symbolic and does not portray real situations, or that medieval images cannot be seen as documentation (see for instance Bolvig 1998), and even if one does not fully subscribe to that, there are still several source-critical considerations to take into account (see for example Liepe 2003; Myrdal 2007).

Most of the medieval images with looms or weaving frames are depictions of the Virgin Mary; a few are of mythical weavers like Arachne and Penelope or other people. According to Laura F. Hodges (1990), images of the Virgin Mary weaving (as opposed to spinning) appear in medieval art with increasing frequency from the 11th century onwards, while Gail McMurray Gibson argues that they only became common in Western art after the Byzantine Feast of the Presentation of the Virgin was introduced in Western Europe in 1372 (Gibson 1990). The images relate back to the apocryphal story of the Virgin Mary as a temple virgin, praying and weaving in the seclusion of the temple in Jerusalem (Gibson 1990). Gibson's discussion on the layers of symbolic meaning of the textile-working Virgin clearly demonstrates the complexity of these images, but the symbolism of the crafts depicted does not necessarily contradict the actual physical activity of spinning or weaving. As art historian Michael Camille states: "We should not see medieval culture exclusively as binary oppositions – sacred/profane, for example, or spiritual/worldly" (Camille 2003, 29), while Swedish historian Janken Myrdal points out that "symbolism and realism are not opposed" (Myrdal 2007, 114, my translation).

In her book on brocaded tablet weaving, Nancy Spies has gathered references to seventeen medieval depictions of band weavers – fifteen manuscript illuminations, one mural and one tapestry (Spies 2000, 96). In a Corrections and New Information document on her web page, another thirteen illuminations are added to this list (Spies

Corrections). The looms depicted in these images range from simple constructions (two upright posts without any visible support and a warp stretched between them) to what appears to be purpose-built frames. Several of the looms show the warp mounted horizontally *on its side* between the posts, with the front and back of the band facing sideways. In Spies's discussion of the looms and weavers, the images are taken very much at face value, but allowance is made for allegorical elements and artistic licence (Spies 2000, 100–101). According to Spies, about half of the illustrations can be said to show tablet weaving as opposed to ordinary band weaving. In these cases, there are visible tablet-like objects on the warp (Spies 2000, 96). Many of the images in Spies's list are available in various online databases (for example *Liber Floridus*; *Mandragore*; *Luna – Bodley Oxford*; *Corsair*) and several are reproduced in Wyss (1973).

The idea of the loom type used by the Virgin Mary seems to be a persistent one, considering the number of images showing the same kind of construction over a long period of time (at least from the early 14th century to the beginning of the 16th century). There is also the find of a 9th century floor-standing frame from the ship burial at Oseberg, Norway, that has been interpreted as a band or tablet weaving loom (Christensen and Nockert 2006, 156; Falk *et al.* 1928, 173–174). Although it pre-dates the medieval images by 500 years, the resemblance is quite striking and it adds a certain credibility to the later depictions (compare with Figures 4.1 and 4.2, and illustrations in Wyss 1973 and Falk *et al.* 1928).

For obvious reasons, the perspective of the author is slightly different from that of art historians. Many of the medieval images of the weaving Virgins and their equipment make sense now, in a way that they did not before work began with Eric of Pomerania's Belt. From the standpoint of a weaver who has tried weaving a complex medieval belt, the potential practical implementation of the looms in these images can be appreciated – they show an alternative way to set up the warp that might make weaving certain types of bands easier:

- weaving with the warp facing sideways would mean that the weaver can look straight down into the shed while working and make sure it is clear
- with the warp facing sideways, it would be easier to look at both the back and the front of the band – the weaver would only need to tilt it sideways a little if she is weaving a double-sided pattern
- with the warp facing sideways, the tablets would be stacked on top of one another – they would be kept in place by their own weight despite being unbalanced

Setting aside the caveats concerning medieval art and viewing the images from a purely technological or practical point of view, the question would simply be: does the loom set up depicted in the images actually work? The only way to answer that is to make a similar loom and weave on it, using the tools seen in the images, so this is what was done (Figure 4.3).

The loom

The loom consists of two upright posts, stabilised with horizontal cross bars, one at the bottom and one at knee height. The warp is wrapped around one post and the finished band around the other. The tablets are made of rawhide as a simple substitute for wood

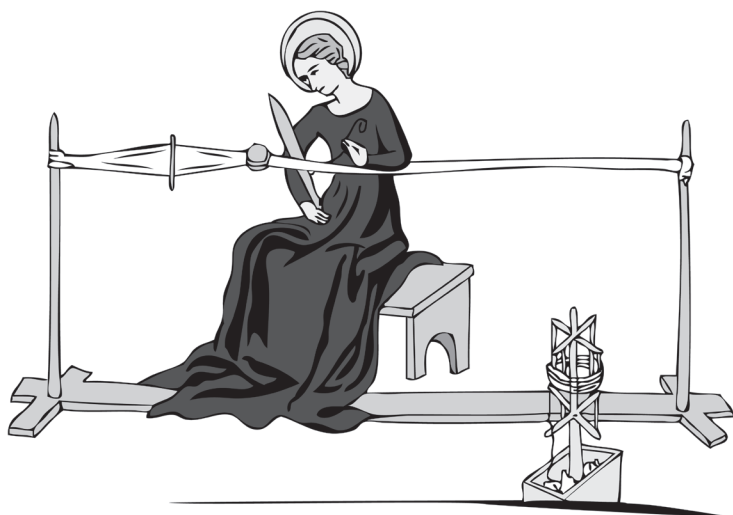


Figure 4.1. *The Virgin Mary at her loom*. From MS Latin 1156 A, fol. 23 r, 1434–1480. Bibliothèque Nationale de France. Drawing: Viktoria Holmqvist.



Figure 4.2. *The Virgin Mary at her loom*. From MS Douce 144, fol. 19 r, 1407. Bodleian Library, Oxford. Drawing: Viktoria Holmqvist.

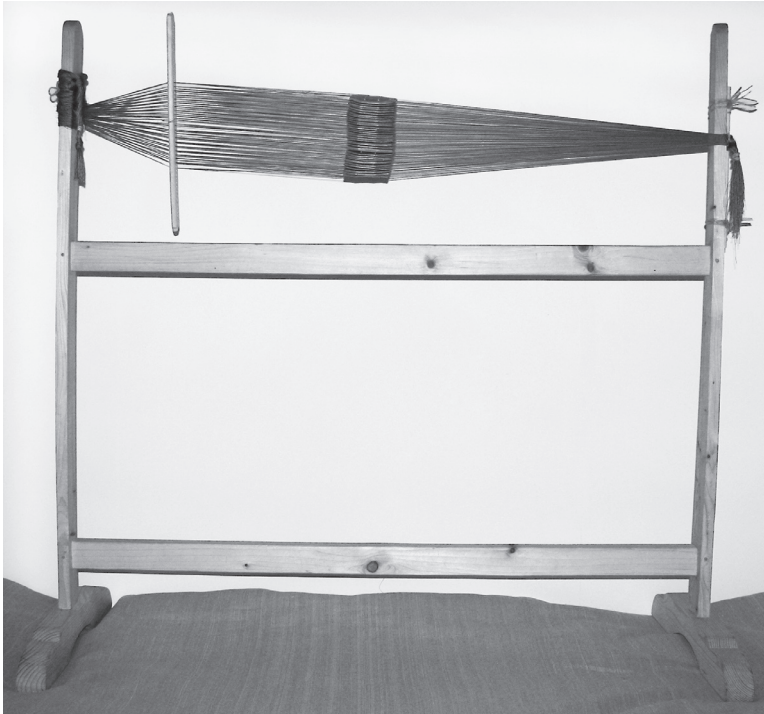


Figure 4.3. Reproduction of a Virgin Mary-type loom. Photo: Viktoria Holmqvist.

or bone, which seems to have been the common material for medieval weaving tablets (see Spies 2000, 93–95). The author usually uses cardboard tablets, but they are much thinner than medieval tablets would have been. In some of the weaving images, the Virgin Mary is handling a substantial pack of tablets and there was a requirement to replicate that. The warp spreader or warp spacer – the stick-like object the warp threads run through – is not an uncommon concept in handweaving. Collingwood describes a comb-like implement used by tablet weavers in 20th century Morocco and China to keep the warp spread out. This makes it easier to turn the tablets and to keep the width of the band constant, especially when weaving a wide band (Collingwood 1996, 40–41). The warp-spreader stick in the medieval images would have the same function.

Weaving with equipment that is unfamiliar and with the warp set up sideways does not come naturally even to an experienced tablet weaver. Usually when weaving, the author does not pay much attention to the tools used; as long as they do their job, the focus is on what can be produced with them instead. Polanyi writes about this as attending *from* a thing, for example a tool, to the effect it has when used (Polanyi 1983, 12–16). The awareness of the tool becomes *subsidiary* to the *focal awareness* of the action it performs and these two kinds of awareness are mutually exclusive (Polanyi 1962, 55–56). If the focal awareness is directed to something that we have only been aware of in its subsidiary role, the result may be clumsiness, self-consciousness and confusion.

This is certainly true of a skilled craftsperson confronted with new tools and a different way of working. The first reaction to weaving on the new loom was that it felt awkward and impractical, but these initial reactions had nothing to do with whether it is a good loom or a bad loom. It was a result of the weaver's focal awareness being forcefully directed to something that is usually not thought about. The tool got in the way of weaving. There was a need to *learn* how to work with the loom; how to sit in relation to it, how to handle the stack of tablets and how to 'think' the weaving sideways, rather than flat in front where it usually is. A skill is not just knowing how to do something, intellectually and practically – it is also hand-to-eye-to-brain coordination and muscle memory and those things need practice to re-develop when the entire work process is suddenly changed.

Weaving with the warp on its side presents some clear advantages: It allows the weaver to watch the shed all the time which makes weaving a complex band like Eric of Pomerania's Belt much easier. Tilting the weaving sideways a little does not upset the warp or the tablets, so it is perfectly possible to look at both the front and the back the band while weaving. The tablets are surprisingly secure when they lay stacked on top of one another and do not move unless they are made to, even on a slippery silk warp. A large beater, like the one used by several of the weaving Virgins, has the necessary weight behind it to pack the weft properly with only one beat (compare with the modern weighted beaters in Collingwood 1996, 40) and it rests more securely in the shed than a lighter one does. Propping the beater in the shed (as the Virgin does in MS M 359, fol. 26 v (*Corsair*), for example) is a simple insurance against mistakes; if there is something wrong with the new shed, it is relatively easy to go back to the previous one held open by the beater. A few other uses for the warp spreader were found; moving it up or down the warp adjusts the tension and if it is moved really close to the tablets, it locks them in place and secures them for pauses in the weaving.

Does this study say anything about weaving practices in the past? Although many of the observations are interesting from a practical point of view, all that can be said with certainty is that the principle of the looms depicted in many of the weaving Virgin images is sound. They work if the weaver takes the time to learn how to use them. In the more detailed images (see for example Figure 4.4, or The Hague, KB, 76 F 21, fol 14 r (*Medieval Illuminated Manuscripts – KB*), all of the features – the position of the warp, the use of a warp spreader and the over-sized beater – have a practical purpose that facilitates weaving complex tablet weaves such as Eric of Pomerania's Belt. However, it is impossible to say if looms like these were commonly used in medieval times – or where they were used, or by whom – unless other sources can be found to shed light on that.

Concluding remarks

As shown in this study of Eric of Pomerania's Belt, the combined perspectives of traditional research and practical skills can produce a fuller, more accurate description of a historical textile. In this case, the practical knowledge of weaving was able to take over when the standard technical analysis was unable to identify what turned out to be a previously undocumented tablet-weaving technique. However, the practical work needed to be critically assessed and evaluated just like any other source.



Figure 4.4. *The Virgin Mary at her loom, with Jesus at her feet. From Vita Christi. Sp Coll MSS Hunter 36–39, vol. 1, fol. 80 v, 1490s. The University of Glasgow. Drawing: Viktoria Holmqvist.*

A craftsperson may see things an academic researcher might not even know to look for in the archaeological material. Observations coming from a practical point of view are invaluable in a research situation, as they might question preconceived ideas about practices and lead to a change of perspective. At the same time, modern craftspeople may have preconceived ideas of their own concerning their craft. The contribution of a craft skill should therefore be analysed in the context it is being used.

The nature of crafts often makes modern-day practices unsuitable to use as a basis for broad generalisations about the past. Something that seems obvious and clear-cut may only be that in a specific situation or to a particular craftsperson. But used in an open and reflective way, the combined strengths of theory and practice will inevitably lead to the increased knowledge of historical textiles and the crafts that produced them.

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References

- Andersson Strand, E. (2010) Experimental Textile Archaeology. In Andersson Strand, E., Gleba, M., Mannering, U., Munkholt, C. and Ringgaard, M. (eds), *North European Symposium for Archaeological Textiles X*. Oxford, Oxbow Books, 1–3.
- Bolvig, A. (1998) Images of Late Medieval 'Daily Life': A history of mentalities. *Medium aevum quotidianum*, vol. 39.
- Bender Jørgensen, L. (2007) Archaeological Textiles between the Arts, Crafts and Science. In Rast-Eicher, A. and Windler, R. (eds), *Archäologische Textilfunde – Archaeological Textiles. NESAT IX*. Ennenda ArcheoTex.
- Camille, M. (2003) *Images on the Edge: the Margins of Medieval Art*. London, Reaktion Books Ltd. first edn, 1992.
- Christensen, A. E. and Nockert, M. (eds) (2006) *Osebergfunnet*. Bd 4, Tekstilene. Oslo, Kulturhistorisk museum, Universitetet i Oslo.
- Coles, J. M. (1979) *Experimental Archaeology*. London, Academic Press.
- Collingwood, P. (1996) *The Techniques of Tablet Weaving*. McMinnville, Robin and Russ Handweavers, Inc. First edn, 1982.
- Corsair (Pierpont Morgan Library). [<http://corsair.themorgan.org/>]. Image database, accessed 2011.11.23.
- Cunningham, P., Heeb, J. and Paardekooper, P. (2008) Introduction. In Cunningham, P., Heeb, J. and Paardekooper, P., *Experiencing Archaeology by Experiment*. Proceedings of the Experimental Archaeology Conference, Exeter 2007. Oxford, Oxbow Books, v–ix.
- Falk, H., Brøgger, A. W. and Shetelig, H. (eds) (1928). *Osebergfundet*. Bd 2. Oslo.
- Fingerlin, I. (1971) *Gürtel des hohen und späten Mittelalters*. München Berlin, Deutschen Kunstverlag.
- Franssen, M., Lokhorst, G.-J. and van de Poel, I. Philosophy of Technology. In *The Stanford Encyclopedia of Philosophy* (Spring 2010 Edition) Accessed online 2011–12–08: [<http://plato.stanford.edu/archives/spr2010/entries/technology/>].
- Gibson, G. M. (1990) The Thread of Life in the Hand of the Virgin. In Holloway, J. B., Bechtold, J. and Wright, C. S. (eds), *Equally in God's Image: Women and the Middle Ages*, originally published, New York and Berne, Peter Lang Publishing. Accessed as E-Book 2011–08–31: [<http://www.umilta.net/equally.html>],
- Hansen, C. (2008) Experiment and Experience: Practice in a Collaborative Environment. In Cunningham, P., Heeb, J. and Paardekooper, P., *Experiencing Archaeology by Experiment: Proceedings of the Experimental Archaeology Conference, Exeter 2007*. Oxford, Oxbow Books, 69–80.
- Hodges, L. F. (1990) Noe's Wife: Type of Eve and Wakefield Spinner. In Holloway, J. B., Bechtold, J. and Wright, C. S. (eds), *Equally in God's Image: Women and the Middle Ages*, originally published, New York and Berne: Peter Lang Publishing, 1990. Accessed as E-Book 2011.08.31: [<http://www.umilta.net/equally.html>]
- Holmqvist, V. (2010) A Study of Two Medieval Silk Girdles: Eric of Pomerania's Belt and the Dune Belt. In Andersson Strand, E., Gleba, M., Mannering, U., Munkholt, C. and Ringgaard, M. (eds), *North European Symposium for Archaeological Textiles X*. Oxford, Oxbow Books, 117–128.

- Holmqvist, V. (2007) *Girt with a Ceint of Silk, with Barres Smale: A Study of the So-Called 'Eric of Pomerania's Belt'*. Unpublished bachelor's thesis, Höskolan i Borås.
- Medieval Illuminated Manuscripts – KB* [<http://www.kb.nl/manuscripts/>]. Image database, accessed 2011–12–09.
- Latour, B. (1999) Circulating Reference. Sampling the Soil in the Amazon Forest. In *Pandora's Hope. Essays on the Reality of Science Studies*. Cambridge, Massachusetts, Harvard University Press, 24–99.
- Liber Floridus*. [<http://liberfloridus.cines.fr/>]. Image database, accessed 2011–11–23.
- Liepe, L. (2003) On the Epistemology of Images. In Bolvig, A. and Lindley, P. (eds), *History and Images: towards a new iconology*. Turnhout, Brepols Publishers, 415–430.
- Luna – Bodley Oxford*. [<http://bodley30.bodley.ox.ac.uk:8180/luna/servlet>]. Image database, accessed 2011–11–23.
- Mandragore*. [<http://mandragore.bnf.fr/html/accueil.html>]. Image database, accessed 2011–11–23.
- Mathieu, J. R. (2002) Introduction – Experimental Archaeology: Replicating Past Objects, Behaviors, and Processes. In Mathieu, J. R. (ed.), *Experimental Archaeology: replicating past objects, behaviors, and processes*. BAR International Series 1035. Oxford, Archaeopress, 1–11.
- Mathieu, J. R. and Meyer, D. A. (2002) Reconceptualizing Experimental Archaeology: Assessing the Process of Experimentation. In Mathieu, J. R. (ed.), *Experimental Archaeology: replicating past objects, behaviors, and processes*. BAR International Series 1035. Oxford, Archaeopress, 73–82.
- Molander, B. (2003) *Vetenskapsfilosofi: en bok om vetenskapen och den vetenskapande människan*. Stockholm, Thales. First edn, 1988.
- Myrdal, J. (2007) Medeltida konst som källa till realia. In Öberg, J., Kihlman, E. and Melin, P. (eds), *Den mångsidiga målaren. Vidgade perspektiv på Albertus Pictors bild- och textvärld*. Runica et Mediaevalia, Scripta maiora 4. Södertälje, Sällskapet Runic et Mediaevalia – Stockholms Universitet, 113–122.
- Narmo, L. E. (2010) Handcraft as Time Travel. *Lund Archaeological Review*, vol. 15–16, 2009–2010, 43–60.
- Nørlund, P. (1937) Det saakaldte 'Erik af Pommerns Bælte'. In *Från stenålder till Rokoko. Studier tillägnade Otto Rydbeck*. Lund, Gleerups förlag, 317–323.
- Penna-Haverinen, S. (2010) Patterned Tablet-Woven Bands – in search of the 11th century textile professional. In Andersson Strand, E., Gleba, M., Mannering, U., Munkholt, C. and Ringgaard, M. (eds), *North European Symposium for Archaeological Textiles X*. Oxford, Oxbow Books, 196–200.
- Polanyi, M. (1962) *Personal Knowledge. Towards a Post-Critical Philosophy*. Chicago, University of Chicago Press. First edn, 1958.
- Polanyi, M. (1983) *The Tacit Dimension*. Gloucester, Massachusetts, Peter Smith. First edn, 1966.
- Reynolds, P. (1999) Butser Ancient Farm, Hampshire, UK. In Stone, P. G. and Planel, P. G. (eds), *The Constructed Past: experimental archaeology, education and the public*. London, Routledge, 124–135.
- Schön, D. A. (1983) *The Reflective Practitioner: how professionals think in action*. New York, Basic Books.
- Spies, N. (2000) *Ecclesiastical Pomp and Aristocratic Circumstance: A Thousand Years of Brocaded Tablet woven Bands*. Jarrettsville, Arelate Studio.
- Spies, N. *Corrections*. [<http://www.weavershand.com/epacerrata05.pdf>], accessed 2011–11–23.
- Unionsdrottningen. Margareta I och Kalmarunionen*. (1996). Exhibition catalogue, Nationalmuseum, København, 386.
- Wyss, R. L. (1973) Die Handarbeiten der Maria. In Stettler, M., Lemberg, M. and Abegg, W. (eds), *Artes minores: Dank an Werner Abegg*. Bern, Verlag Stämpfli and Cie, 113–188.

The 13th–16th Century Tablet-woven Bands from Estonia

Ave Matsin

Tablet weaving is one of the oldest weaving methods of bands. Owing to poor soil preservation and the cremation rituals that were prevalent until the 13th century, it is not possible to trace this type of band used in clothing back to earlier times. This article presents an overview of archaeological findings from the 13th–16th centuries of tablet-woven bands in Estonia. The article focuses on individual bands as well as different techniques used for edging clothing items. The main source for the archaeological findings is Siksali cemetery (12th–15th century) in South Estonia where tablet-woven bands are used in combination with many bronze artefacts to decorate clothing items. Due to the rich usage of bronze artefacts, these tablet-woven bands have been better preserved.

The oldest archaeological textile finds, in what is now Estonia, the northernmost of the three Baltic countries, date from the 3rd century CE (Peets 1992, 65). In spite of this, the first consistent artefacts are from the late 12th century, the 11th century in some locations (Peets 1993, 216). A particular local feature is the use of cremation from the Late Bronze Age to the first decades of the second millennium, which means that finds of textiles from earlier periods are rare. A large number of textile fragments, largely imported from Western Europe, have been found in the medieval and post-medieval cultural strata of cities (Rammo 2010). Items of clothing found in bogs and burial sites provide an overview of local textile production. The Estonian soil does not favour the preservation of textile from vegetable fibre and thus the principle part of the old textiles that are extant today are from wool.

Of the techniques used for Estonia's archaeological textiles, the most common are weaving, needlework and the plaiting of various belts, straps and ribbons. One of the oldest techniques for making bands and ribbons is tablet weaving. The only ancient weaving tablets in Estonia were found in the Lõhavere hillfort in southern Estonia and have been dated to the early 13th century (AI 4133: 2274: 76) (Peets 1992, 74). The oldest



Figure 5.1. Reconstruction of the Virunuka back apron along with tablet-woven belt made by Jana Ratas. Photo: Jaak Mäll.

weaving tablet fragments were found in the Loona, Hummuli and Jõuga cemeteries which have been dated to the 12th century (Peets 1992, 75).

This article gives an overview of finds of tablet weaving, the techniques for making them and functions of their use. It shall focus on the fragments of tablet weaving found at Siksali cemetery, located in southern Estonia, which yielded abundant archaeological material, as well as the process of reconstructing them. Some foreign brocade ribbons dating back to the 13th century have also been found in Estonia (Peets 1992, 98), but these will not be described at length in this article.

Most of the archaeological fragments of Estonia's tablet-woven bands are related to items of clothing and only a few are standalone ribbons. The oldest known tablet-woven band fragment is from the Jõuga cemetery and dates to the early 12th century (AI 3713 VII: 27) (Peets 1992, 75). This is a 1.5 cm wide all-wool ribbon woven on 14 tablets: 1 four-thread tablet on each side and 12 two-thread tablets in the middle. Double threads with an S/zz twist were used to weave the regular rhombic pattern. The number of tablets and use of material is conventional in the context of Estonian archaeological finds and typical of ribbons of local origin.

The most ornate tablet-woven band (AI 4342: V 9, 10) is a wide ornamented ribbon found in the southern Estonian Virunuka cemetery. It dates from the 13th–14th centuries and three fragments survive. The fragments indicate that the belt was 4 cm wide and woven on 40 tablets: 4 four-thread tablets on each side and 32 two-thread pattern tablets in the middle. In general most of the older tablet-woven belts are characterised by the middle tablets being two-thread. The belt was found associated with a distinctive back apron (Laul 1981), which it is likely that the belt was used to fasten (Figure 5.1)

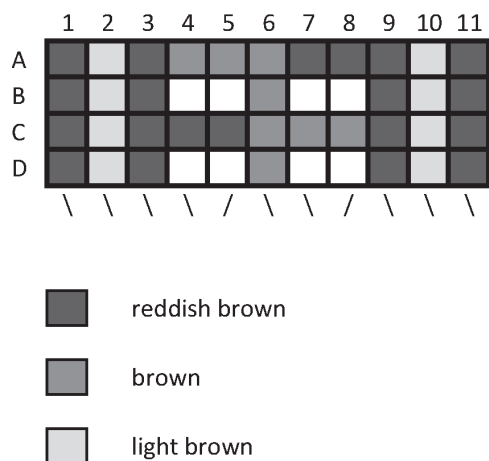


Figure 5.2. System for the Parisselja tablet-woven band (ERM 19506: 6). Drawing: Ave Matsin.

leggings and ribbons was dated to the 14th–15th centuries (Moora 1957, 16). Two woollen tablet-woven band fragments are extant (ERM 19506: 6) with a total length of 162 cm. The width of the belt was 2.5 cm and 11 tablets were used to weave this relatively thick belt. Like most of the older tablet-woven bands, the middle tablets are two-thread, but unusually the tablets were turned simultaneously in the weaving process. Three reddish-brown coarse doubled wool threads (S/zz) in different tones were used (Valli 2006, 21). The scheme used for weaving the belt is shown in Figure 5.2.

The Parisselja tablet-woven band is coarser and more robust than its predecessors, characterising well the backwards step in technology, which can be seen over eight centuries up until the early 20th century.

Below is a discussion of examples of the tablet-woven bands used for finishing traditional shawls, aprons and headwear. Two different types of techniques can be distinguished: tablet-woven bands that are woven directly into the clothing and separately woven tablet-woven bands that were attached to the clothing by sewing.

An example of a separately woven tablet-woven band was discovered in Küti cemetery (eastern Estonia) in 1925 (Figure 5.3): fragments of a shawl were found, to the edge of which was attached a tablet-woven band decorated with inlaid bronze spirals (AI 2731: 14, 15) (Kurrik 1932, 114). It is believed that eight tablets were used to weave it. In the centre of the ribbon, the yarn passes through the spirals so that they are between two four-tablet parts of the ribbon. It is likely that similar ribbons were used to decorate other northern and north-eastern Estonian clothing in antiquity. On the basis of the bronze spiral ornaments found from Kukruse, Kaberla and Pada cemeteries which date from the end of the 12th century to the beginning of the 13th century, archaeologist Riina Rammo has conjectured that such ribbons were used to adorn the edges of aprons, and less frequently, overclothing (Rammo 2005; 2006). Although the majority of the textile

Barbro Gardberg has made a reconstruction on the basis of the ribbon fragments (Astel 1998, 32). Similarly to other patterned tablet-woven bands from the same period, a specific distribution was used as a basic system for weaving the middle, patterned part, which will be discussed in greater detail in connection with the Siksali tablet-woven bands (see below, Figure 5.5). What makes the ribbon special is that the pattern order cannot be determined from the extant fragments: the belt was woven not with one pattern repeated over and over but rather with a varying pattern.

Another archaeological textile find from the same period is the older of the two Estonian bog finds. A sleeveless jacket found in Parisselja bog in western Estonia in 1917 (ERM 19506) with associated

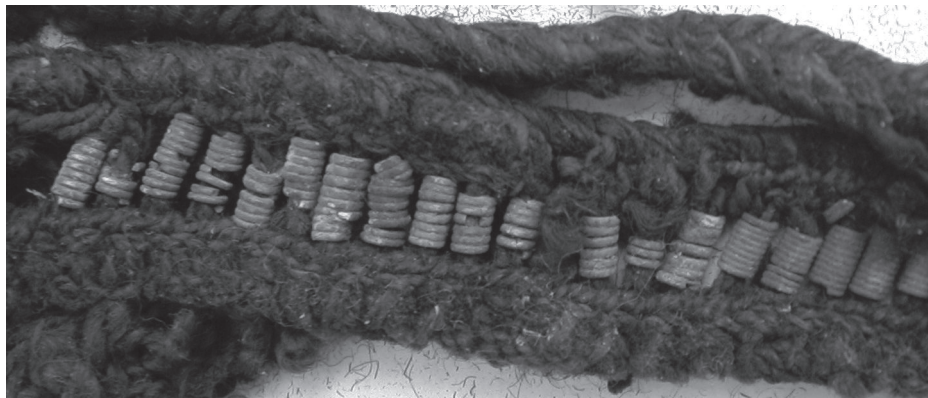


Figure 5.3. Fragment of a tablet-woven band decorated with inlaid bronze spirals (AI 2731: 14, 15). Photo: Riina Rammo.

surrounding the metal is no longer extant, one fragment demonstrates that at least five tablets were used on either side of the spiral – thus a total of at least ten (Rammo 2006, 256). A similar tablet-woven band technique was used in decorating individual textile items in Finland (Rammo 2006, 258).

The Siksali cemetery textiles

The textile finds discovered at Siksali cemetery are extraordinarily rich, being both abundant and well-preserved due to the presence of bronze artefacts. Siksali is located in Vastseliina parish in southern Estonia. The excavations there took place under the supervision of archaeologists Silvia Laul and Jüri Peets from 1980–1993. The cemetery was used from the late Iron Age to the end of the 15th century. There are a total of 279 graves that have been subjected to archaeological investigation, which makes up 4/5 of the cemetery. Earlier burials involved cremation – there were a total of 27 of them. Burials of a total of 89 men and 129 women have been identified (Laul and Valk 2007, 29).

From the second half of the 13th century onwards, the finds have predominantly ‘Latgalian’ characteristics. The latest archaeological theory regarding the inhabitants of Siksälä is that an independent people lived there – not directly related either to the Estonians or Latgalians (Laul and Valk 2007, 145).

The material from Siksali cemetery is of extreme interest to the study of textiles. A great many bronze spirals and clips were used to decorate the clothing. Many of the textiles are similar to Latgalian textiles from the same time (Zariņa 1970). There was also a lavish array of bronze jewellery. The presence of bronze has helped the woollen textiles survive relatively well. Textile fragments were found in most of the graves, which allows the comparison, study and reconstruction of the sartorial development of the inhabitants of one village from the 13th–15th centuries.

Some of the most outstanding women’s clothing items were shawls with abundant

ornaments. Archaeologist Silvia Laul (Laul and Valk 2007, 51–55) states that three different types of these shawls can be identified:

- all-wool twill indigo-blue shawl decorated with bronze clips
- semi-woollen blue and white chequered shawl with flax and wool weft and warp
- semi-woollen patterned shawl with flaxen warp and wool ornamented pattern

The shawl was a relatively small item and practical function was secondary. The precise measurements can be established due to the bronze clips (for example, the shawl from grave 158 measured 81 × 105 cm), but this is only possible for the all-wool indigo shawls. However, it can be presumed that the other shawls were a similar size.

The majority of the tablet-woven band fragments were found either sewn on to the edges of the shawls or woven into the warp threads. As a number of different types of shawls were found in the cemetery, the tablet-woven bands used to decorate them are also different (Laul and Valk 2007, 56). In addition to the shawls, tablet-woven bands were also used to decorate headbands and for making simpler, narrow monochrome belts.

Tablet-woven bands sewn on to the textile

Tablet-woven bands sewn on to the fabric were used for adorning all of the shawls. In spite of the varying use of material, these were woven using a very similar technique and tended to be decorative in terms of function.

The greatest number of tablet-woven bands survived on the edges of the all-wool twill indigo-blue wraps and this is no doubt due to the abundant use of bronze ornaments. Of the 23 of this type of extant shawl, ten have intact traces of tablet-woven bands along the edges. Most of the edge tablet-woven bands on these shawls are all wool. Flax yarn was used for the weft of only two of them. The wool weft material is certainly another key reason for the good preservation of the ribbons. Without exception, the tablet-woven bands were sewn to the edges of the fabric using wool yarn. The width of the tablet-woven bands varies from 10–19 mm but the most common width is 17–18 mm. The number of tablets used was 11–17, the most frequently seen number of tablets was 16–17 (seven out of ten cases). These can be sub-divided into 12 two-thread pattern tablets and 4–5 four-thread edge tablets. The most common system is the one shown in Figure 5.4 based on the tablet-woven bands along the edges of the shawl found in grave 244.

What makes the edge tablet-woven bands interesting is that the motifs used are not repeated symmetrically: the pattern is dynamic and variational. Similar motifs have been grouped in threes, combining the direction and background. Exact repetitions of pattern combinations are extremely rare. Such use of pattern is not seen in later Estonian ethnographic textiles, although tablet-woven bands with a similar composition were used in later Latvian shawls (LTT 1995). The structure of the tablet-woven band pattern is based on similar principles. The basic scheme for the pattern is two light and two dark yarns without variation on every other row; the pattern may be freely chosen on the rest of the rows (the light-coloured ones in the Figure 5.5).

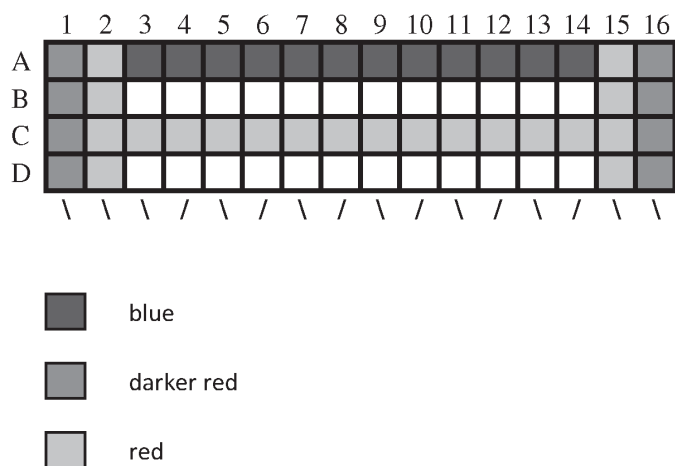


Figure 5.4. Patterned tablet-woven band system (AI: 5101: CCXLIV: 4). Drawing: Ave Matsin.

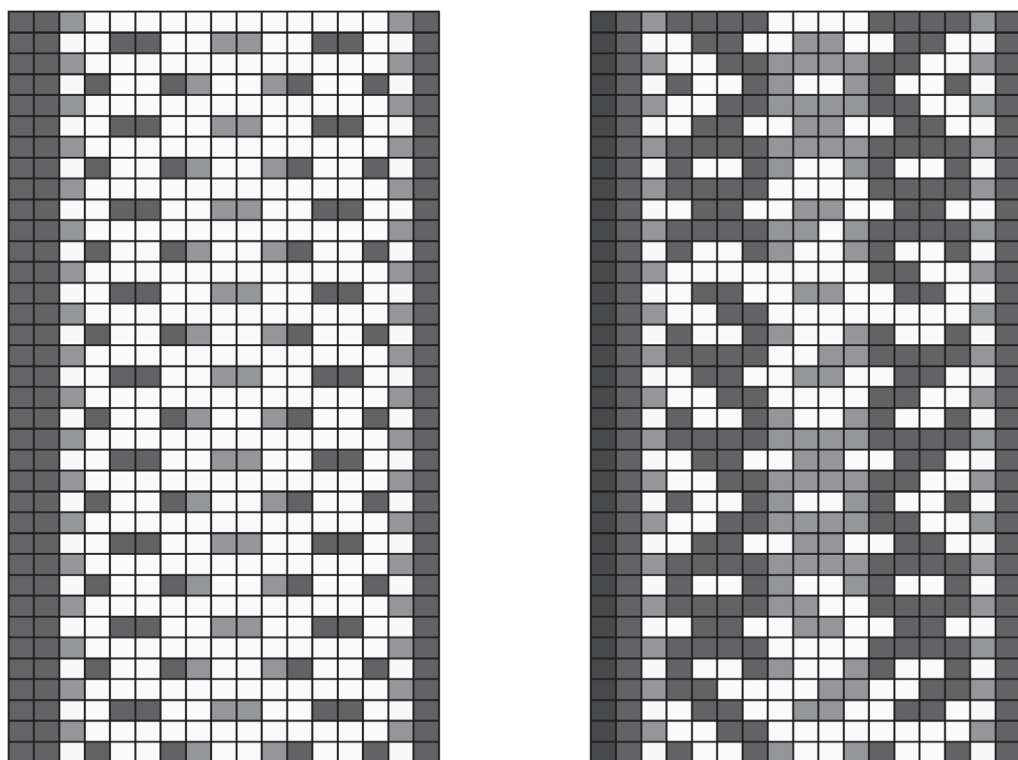


Figure 5.5. Pattern structure. Drawing: Ave Matsin.

There were chequered semi-woollen shawl fragments in a total of 15 graves, but only four had extant tablet-woven bands sewn to the edges. All of the tablet-woven bands are semi-woollen. They have a wool warp and flax weft, which is presumably the reason why the ribbons did not survive the passage of time well. No bronze details were used to adorn these shawls. Overall, the edge tablet-woven bands were woven with a smaller number of tablets than the woven bands on the all-wool shawls: here 2–3 four-thread edge tablets were used on both sides and in the middle, 8 two-thread pattern tablets were used. Only in one case were 12 pattern tablets used, similarly to the all-wool shawls' woven bands. Measurement of the width of the tablet-woven bands is inexact, as due to the lack of the weft threads, the warp threads have come apart. The current measurements of the tablet-woven bands are 14–18mm wide but they were presumably narrower to start with. Three of the tablet-woven bands were attached to the shawl with wool yarn and three were attached with flax yarn. In terms of setup and design, these are very similar to the all-wool shawl edge bands.

Because the semi-woollen patterned shawls were constructed from flax warp threads and an alternating background of flax and wool pattern weft threads, only the smallest fragments have survived. Only the wool weft threads survive, from which the original details of the pattern can occasionally be discerned. As the textile that the tablet-woven bands were attached to no longer survives, it is difficult to analyse the tablet-woven bands used to adorn this type of shawl.

Of the seven surviving shawls with wool weft pattern ornament, the edge woven bands can be seen on five. The extant fragments support Silvia Laul's assertion (Laul and Valk 2007, 56), that the edge tablet-woven bands of this type of shawl had a setup and use of pattern similar to the other shawls discussed above, but used different materials: they make partial use of flax yarn for the warp threads. Wool yarn was used in one opening of the two-thread pattern tablets and flax yarn in the other opening. Flax yarn was used as the weft thread in all cases. Most of the bands were sewn to the shawl using woollen yarn, with only one band sewn on with flax.

Tablet-woven bands woven on to the textile

All of the shawls, in addition to having tablet-woven bands sewn on to the lengthwise edges, had tablet-woven bands woven into the warp threads at the ends of the shawls. This is reminiscent of textiles woven on an upright loom: the warp of the fabric forms the weft of the tablet-woven bands. There are characteristics demonstrating that the bands were woven into the fabric later. The fabric warp is made up of a fringe 10–12 cm long on the side of the band that is not part of the main body of the shawl, which is not usual for upright loom woven fabric. In addition, bronze spirals are threaded between the fabric and the band at the ends of the all-wool bronze-adorned shawls; the spirals would be nearly impossible to add during the warping process. Beside the warp threads of the fabric, additional colourful fringing yarn has been woven through the end bands (Figure 5.6).

Of 23 of the all-wool indigo-blue shawl fragments, eight extant end bands were clearly made using a similar system. The width of the bands is 9–10 mm and there are usually 9–12 tablets, in most cases 11: 2 four-thread edge tablets on both sides and in the middle,

7 two-thread pattern tablets (5 tablets in one case). The patterns used to weave end bands for this type of shawl have a similar structure and so always has an odd number of middle pattern tablets. In the system below (Figure 5.7), because the outermost two-thread tablets (nos 3 and 9) have been rigged with yarn in different colours, a zig-zag pattern appears on the band. This pattern method has been used on all of the all-wool shawls' end bands and on the only extant chequered shawl's end band (AI: 5101: CLVIII: 2a). A similar band is also seen on many Latgalian shawls (Zariņa 1970).

Six patterned shawls have extant bands woven into the ends. Unlike the all-wool and chequered shawls' end bands, a completely different system is used. The system has the same structure in three of the shawls. The main difference consists of the positioning of the yarns in the two-thread pattern tablets (Figure 5.8).

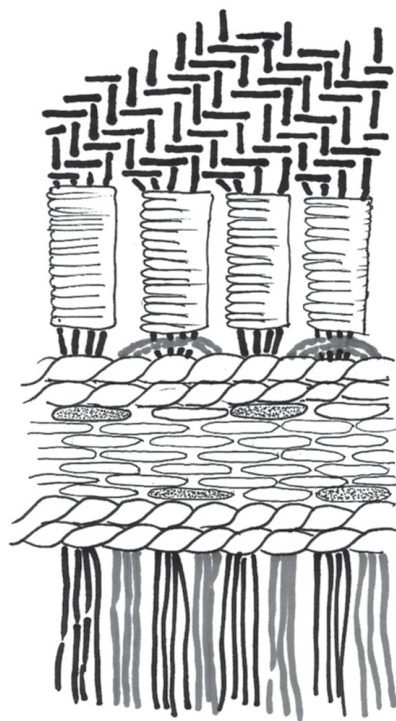


Figure 5.6. System for bands woven on to the fabric. Drawing: Ave Matsin.

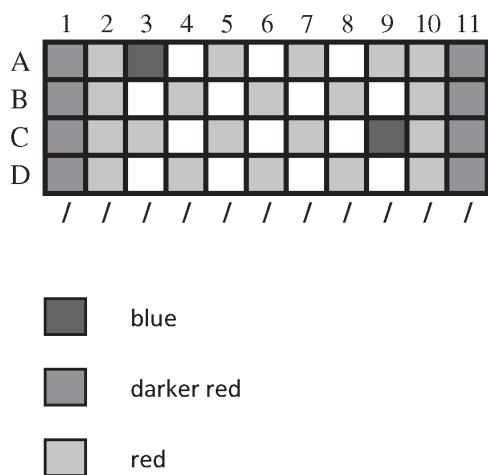


Figure 5.7. System for end bands on all-wool shawl (AI: 5101: CLXXXVII: 12). Drawing by Ave Matsin.

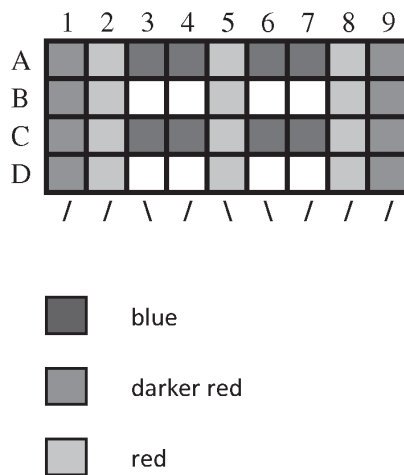


Figure 5.8. System for end bands on patterned shawl (AI 5101: CCXX: 13). Drawing by Ave Matsin.

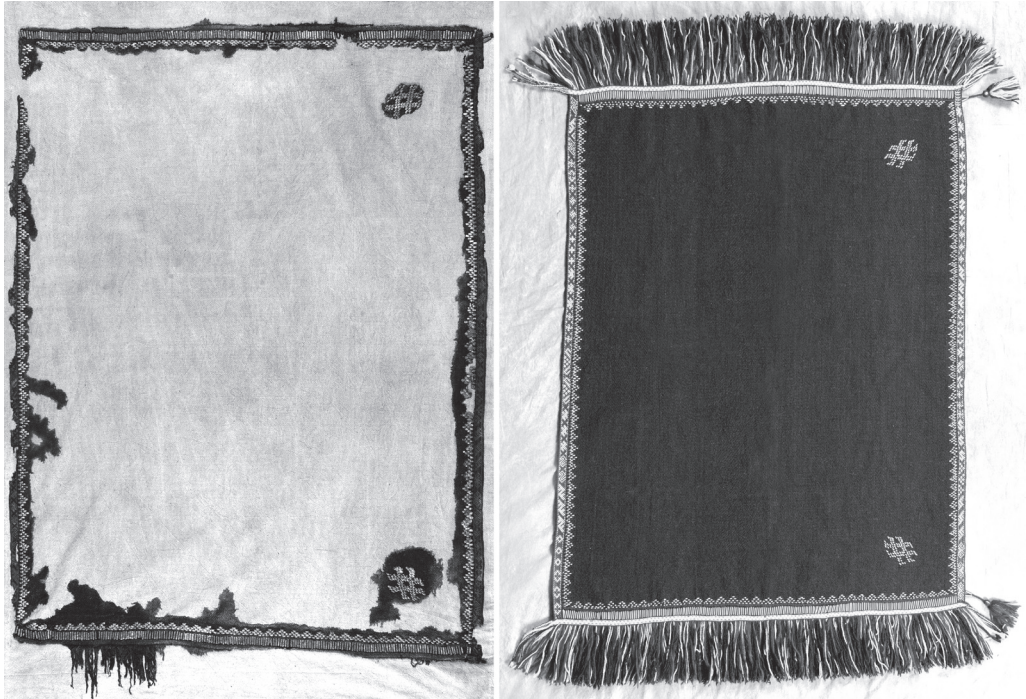


Figure 5.9. *Shawl original (AI 5101: CC: 4) and reconstruction made by Ave Matsin. Photos by Institute of History and Ave Matsin.*

Other tablet-woven bands

In addition to the bands previously discussed, tablet weaving has been used to add end tassels to the edges of head wreaths. It is technically similar to making ribbons woven on to shawl fabric. The tablet technique has been used to a limited extent also for making ribbons woven on four-thread tablets. The technique used for adding the weft means that it is possible to create an additional thread that is perpendicular to the ribbon. A tablet-woven band used as a belt was found in grave no. 200, to which added interwoven weft threads were used to hang objects from the belt. The technique was used to add decorative tassels to the edge woven bands.

Reconstruction

In 2002, the author created a reconstruction of one of the all-wool Siksali shawls adorned with bronze clips (Matsin 2010, 171–190), shown in Figure 5.9. Two goals were set when undertaking the reconstruction: to restore the initial appearance of the object and to obtain new information on the Textile technological tools used in the 13th century for working with textiles, above all the looms.

As noted above, remnants of a total of 23 shawls of this type were found in Siksali,

dating to the 13th–15th centuries. As part of their conservation and preservation, four of the shawls were sewn on to a supportive fabric. This means that it is now possible to see the size and placement of the original fragments (Figure 5.9). The shawls are from graves no. 158 (AI 5101: CLVIII: 2), no. 187 (AI 5101: XCXXXVII: 12), no. 200 (AI 5101: CC: 4) and no. 244 (AI 5101: CCXLIV: 4) and date to the 13th–14th centuries (Laul and Valk 2007, 50). Of these four shawls, shawl no. 200 was chosen for reconstruction as it had the best preserved tablet woven bands. All of the other shawls were conserved as separate fragments.

On the basis of visual inspection, it can be presumed that all four shawls were indigo blue and were adorned by bronze spirals, clips and patterned tablet-woven bands. Similar characteristics can be seen in the compositional structure of the items: the shawls are framed on four sides with ornaments formed from bronze clips. In three cases, the ornamentation was a simple triangular saw-tooth pattern and in one case (no. 158), a more complicated horned ornament. The shawl with the latter ornament is different from the others through one other detail – it lacks the bronze spirals threaded into the warp of the fabric to decorate the end edges. In addition to the edge decorations made of bronze clips, all of the shawls have separate clip motifs in their corners. Three shawls have four corner motifs and one (no. 200) has two. In addition to the difference in the number, the direction of fastening of the clips used to form the motifs differs: the three shawls with four corner motifs have the clips running parallel to the direction of the weft, but in the shawl with only two corner motifs the clips are fastened diagonally. At the same time, it became evident from comparison of the motifs, that on most of the shawls, the edge ornaments along the lengthwise edges were different to the ornaments of the other edges. This shows that the ornamentation of the shawls did not adhere to a strict symmetry and it is likely that shawl no. 200 did not have motifs along the other lengthwise edge. Lack of symmetry was also proved by an examination of the tablet-woven bands: brighter-coloured yarns were used in weaving the core of the tablet band on the motif-bearing edge of the same shawl.

Shawl no. 200 was chosen for reconstruction because it had the best-preserved tablet-woven bands in the original. Grave no. 200 was opened during an excavation in 1988 and studied under the supervision of Silvia Laul (Laul 1988, 3–4). The remains of a 20–25 year old woman were in a log-casket and the position of the deceased was with the head to the northeast. The arms were bent at the elbow and crossed over her chest, over the shawl. The shawl was wrapped so that the loose ends were on the left side of the body. In addition to the shawl, presumably flax shoulder cloth fragments adorned with beads and small tin studs, semi-woollen textile fragments with wool weft pattern ornament on a linen background, a head wreath adorned with beads and bronze spirals and a necklace of cowry shells and beads were discovered. Both wrists were adorned with wide bronze bracelets, with two rings on the right hand and one on the left. There were also two horseshoe brooches on the textiles.

The width of the wool shawl was presumably 83.5 cm and the length without fringes was 107.5 cm. The weave was 2/2 twill. The density of the warp was 11 threads per centimetre and that of the weft was 8–9 threads per centimetre. A smooth and high-quality single thread of Z twist had been used in both directions. All four sides of the shawl were adorned with bronze clips placed in the shape of a triangle, with the total

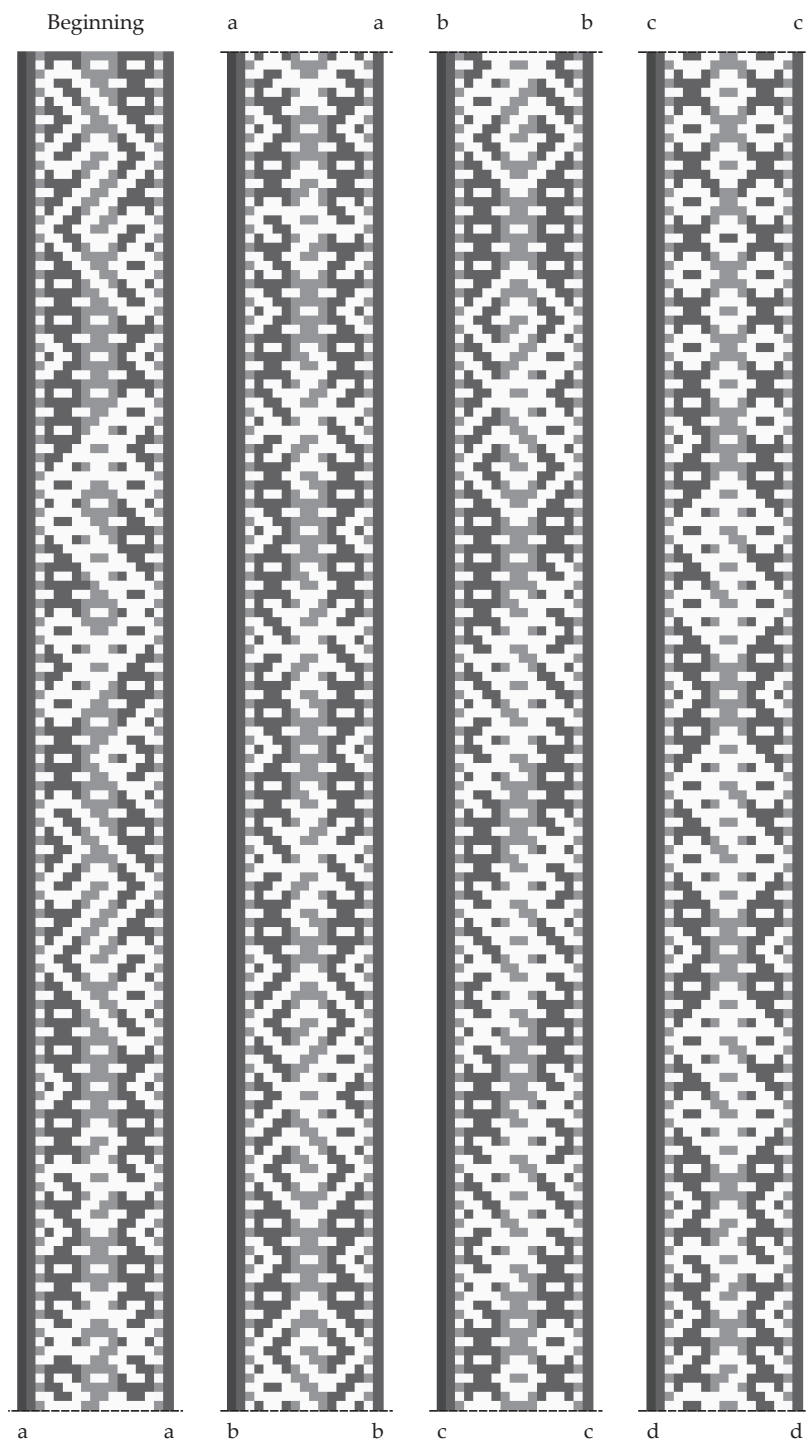
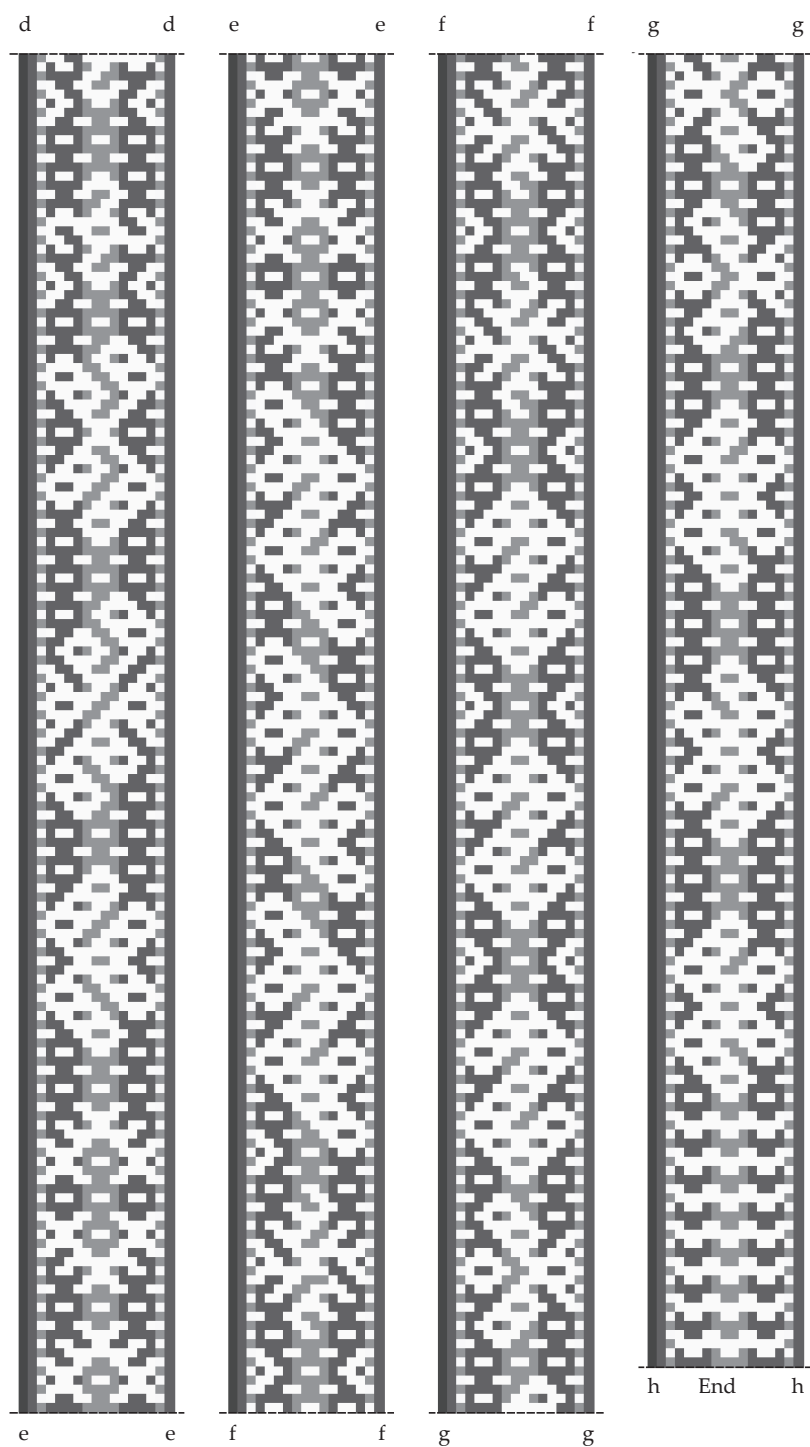


Figure 5.10 The pattern of the tablet-woven band at the lengthwise edge of the shawl. Drawing: Ave Matsin.



of 1,458 clips. A total of 176 additional clips were used to form motifs on two corners of the shawl. A total of about 1,634 clips were used for adorning the shawl. There were 400 bronze spirals attached to the warp between the fabric and tablet-woven bands at the ends of the shawl; each spiral is 14 mm long and with the 4mm diameter from the outer edge.

Seventeen tablets were used to weave the bordering tablet woven bands: 12 pattern tablets in the middle threaded with two threads, two four-thread tablets on one edge and three on the other. The tablet-woven band is 1.7 cm wide. Like other tablet-woven bands of this type, the bordering bands on this shawl were woven with a unique pattern formed by ornamental motifs grouped in threes (see above, Figure 5.10). The pattern is formed by separate turning of each of the two-thread tablets.

Based on the original, fine double wool yarn was used to weave all of the tablet-woven bands. When working on the reconstruction, it was difficult to find yarns with the suitable thickness: the ordinary modern local double yarns were not fine enough for weaving the band on the same scale. The weaving technique was that used to weave Latvian ethnographic tablet-woven bands. The tablets were set up as shown in Figure 5.4. The outermost four-thread tablets were turned simultaneously a quarter of a turn in the same direction. To weave the middle two-thread part, the tablets are turned by row alternately towards then away from the weaver. Only the tablets that need to change to change the thread colour to form the pattern are turned.

The tablet-woven band woven into the warp of the main fabric of the shawl made use of 11 tablets: the seven tablets in the middle were threaded with two threads and the two tablets on each edge with four threads (see Figure 5.7). The band is 1 cm wide. In weaving the band, all tablets were simultaneously turned a quarter of a turn at a time in the same direction. Instead of the weft yarn the warp of the fabric serves as the weft of the bands. Additional colourful fringing yarn has been woven through the bands in alternate rows (Figure 5.6). At the ends of the tablet-woven bands, the warp threads have been braided together.

After the fabric woven on an upright loom was finished, the border band was sewn on to the shawl. The end band was then woven into the warp of the fabric, using the warp of the main body of the shawl as the weft of the tablet woven band (Figure 5.11). Technologically, the finishing of the shawl is very sophisticated and well-considered.

Summary

Relying on archaeological textile finds, it can be stated that tablet weaving techniques were in widespread use in Estonian areas from at least the 12th century. Considering the range of tablet woven bands of this date, it is likely the technique was used in earlier times as well. All of the surviving tablet-woven bands are known to have been used as a clothing accessory: in some cases as a standalone ribbon or belt, but mostly sewn or woven on to clothing. Mostly the tablet-woven bands are all-wool. Only a few ribbons adorning semi-woollen fabrics found in the Siksali cemetery in southern Estonia use flax yarn in the weft and in some case in the warp. The most common system used four-thread tablets at the edges and two-thread tablets in the middle. The tablets were turned in unison for weaving simpler bands, while more complicated bands involved



Figure 5.11. Detail of the corner of the shawl. Photo: Kristi Jõeste

turning the middle two-thread tablets individually as the pattern dictated. Southern Estonian tablet woven band ornamentation makes use of constantly changing patterns, similarly to a number of Latvian archaeological and ethnographic objects: the pattern is never repeated. The finds in Siksali cemetery give an overview of the variations seen in tablet weaving. At first glance similar, the bands used different materials and composition techniques based on their function. Study of the surviving bands shows this to be the most common method for making the bands.

In general, the later tablet woven band technique became simplified in Estonia as in the Nordics. For the most part, the bands in ethnographic materials were simple four-thread tablet woven bands whose pattern was regular and repeating. Only in certain southern Estonian regions and Muhu island in western Estonia were there bands in the late 19th century where the middle part of the band, usually of six tablets, was made with two-thread tablets turned separately two at a time as the pattern dictated. This weaving method is the last recollection of earlier tablet weaving technologies.

References

- Astel, E. (1998) *Eesti vööd*. Tartu.
 Kurrik, H. (1932) Kõlavöö Eestis. *Estonian National Museum Yearbook* 7. Tartu, 93–124.
 Laul, S. (1981) Tagapõll muinaseesti naise rõivastuses. *Eesti ajaloo probleemid*. Tallinn, 76–89.
 Laul, S. (1988) *Report on a dig at Siksali cemetery in Vastseliina parish, 7 July–23 August 1988* Institute of History archaeology archive

- Laul, S. and Valk, H. (2007) *Siksälä: a community at the frontiers, Iron Age and Medieval*. Tallinn, Tartu.
- LTT. (1995) *Latviešu tautas tērpi*. Riga.
- Matsin, A. (2010) Varakeskaegse naise sõba rekonstruktsioon Siksali (Siksälä) kalmistu leiu põhjal. In Tamla, U. (ed.). *Ilusad asjad. Tähelepanuväärseid leide Eesti arheoloogiakogudest. Muinasaja teadus* 21. Tallinn, 171–190.
- Moora, H. (1957) Eesti rahvarõivaste arenemise ajaloost. *Eesti rahvarõivaid XIX sajandist ja XX sajandi algult*. Tallinn, 7–28.
- Peets, J. (1992) *Eesti arheoloogilised tekstiilid kalmetest ja peitleidudest III–XVI saj.* Master's degree thesis. Tartu, Tallinn. Manuscript in University of Tartu Library.
- Peets, J. (1993) Tekstiilileide Ida-ja Kirde- Eestist muinas- ja keskaegsetelt kalmetelt. In Lang, V. (ed.), *Vadjapärased kalmed Eestis 9.–16. sajandil. Muinasaja teadus* 2. Tallinn, 215–232.
- Rammo, R. (2005) *Pronksspiraalkaunistused rõivastel Eesti haualeidude põhjal 11.–14./15. sajandil*. Diploma thesis. Tartu. (Manuscript in University of Tartu archaeology library).
- Rammo, R. (2006) Eesti arheoloogilistest põlleleidudest. In Valk, H. (ed.), *Etnos ja kultuur. Uurimusi Silvia Laulu auks. Muinasaja teadus* 18. Tartu, Tallinn, 249–266.
- Rammo, R. (2010) Social and Economic Aspects of Textile Consumption in Medieval Tartu, Estonia. In Andersson Strand, E.; Gleba, M., Mannering, U., Munkholt, C. and Ringgaard, M. (eds), *North European Symposium for Archaeological Textiles X*, Oxford, Oxbow Books, 201–207.
- Valli, M. (2006) *Rekonstruktsioon Parisselja rabast leitud tekstiilesemetest*. Diplomitöö. Viljandi. (Manuscript in University of Tartu Viljandi Culture Academy library).
- Zariņa, A. (1970) *Seno latgaļu apģērbs* 7.–13. gs. Riga.

Textile Techniques of the Stone Ages

Anne Reichert

The textile production techniques that pre-date the Neolithic invention of spinning and weaving can be undertaken on the raw materials without tools. Bast, rushes, stinging nettles, grasses, reeds and bark can be transformed through twisting and twining into threads, cords and ropes. Weft-twining or plain-twining variations can be used to manufacture hats, sandals, capes, mats, bags and other artefacts. Different techniques can be used to manufacture nets. There are diverse methods to construct baskets. In Europe, prehistoric plant material is only preserved in continuously submerged or frozen sites. The finds from these Neolithic sites allow an understanding of the manufacturing techniques. This article describes and illustrates reconstructions of these artefacts.

Twisting and twining

A wide array of organic material can be used to tie or fasten things: stems of grass, reeds, rushes, strips of bast, *etc.* When the material is very fine – for example fibres of wool, nettle, flax or hemp – some fibres can be twisted together to make a yarn which is stronger than some separate fibres. This technique is also called spinning and mostly a tool is used. In Neolithic times this tool was a spindle with a whorl (Capitani and Leuzinger 1998, 249, fig. 3.10). If the thread is twisted very strongly, it will twist around itself when it is slackened, *i.e.* it will be doubled back on itself. The result is a twined (plied) cord which is much stronger than the twisted (spun) thread, but has only about half of its former length.

In Palaeolithic times spindles were unknown – but the twining technique was already used (Glory 1958). Twined yarn, threads or cords of any length can be made without any tool and with nearly any material which does not break while being twisted, such as bast (*i.e.* the layers between the bark and the wood of a tree; Reichert 2007, 203–206), rushes and different sorts of grass, or other plant fibres such as nettle (Figure 6.1).



Figure 6.1. Twined cords of different diameter from lime bast, rushes, and stinging nettles.

The technique is very simple (Figure 6.2). Several bast strips (or reeds, rushes, grass stalks, stinging nettle fibres, *etc.*) are knotted together at one end and divided into two equally thick bundles. The knot must be held tightly between the right thumb and the forefinger. Then one of the bundles is twisted in a clockwise direction (*i.e.* to the left, direction *z*), and put over the second bundle (in an anti-clockwise direction, *i.e.* to the right, direction *S*). The crossing point must be fixed between the right fingertips. Then the procedure must be repeated with the second bundle, and so on. If, after a turn, the twisted bundles are spread slightly, while holding the whole thing securely, the twined string will become tighter and more regular. It is important always to keep to the chosen twisting direction! Of course, the same small movements can be done with the fingers of the right hand holding the strips in the left.

With this technique, using only the fingers, threads, cords and ropes of any diameter can be made. Depending on the direction of the beginning, the cord is called *z*-spun *S*-plied or *zS*-twined, and *s*-spun *Z*-plied or *sZ*-twined respectively. The fibres of the *zS*-twined cord show the same direction as the middle stroke of the letter *S*, the fibres of the *sZ*-twined cord that of the middle stroke of the letter *Z* (Seiler-Baldinger 1991,

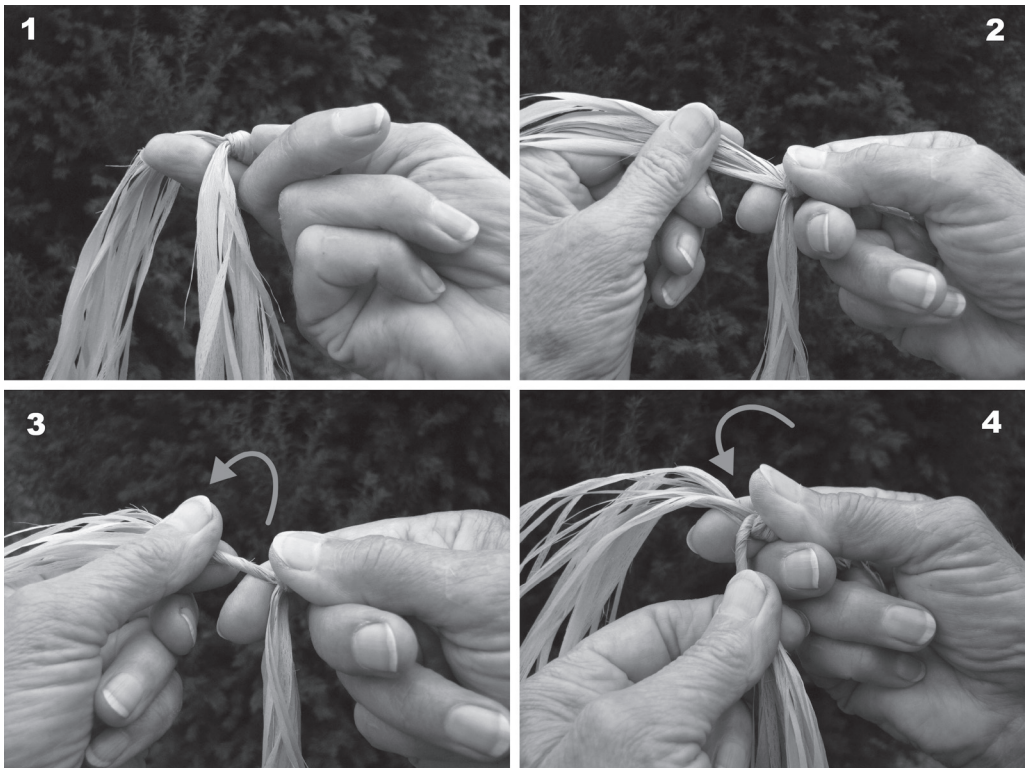


Figure 6.2. Twining. Reconstruction and photo: Anne Reichert.

10, fig. 1). The solidity does not depend on the direction of twining, but only on the thickness of the cord, the used material and the tightness (the angle) of twining.

Particularly strong cords can be made by twining together two twined cords using the opposite direction. Twined cords are much stronger than plaited ones with the same diameter because each strand was twisted twice. Both techniques were used in Mesolithic times (Kernchen and Gramsch 1989), but also in the Palaeolithic ropes were twined as the impression of a rope in clay from the cave of Lascaux, France, shows (White 1986, 47–49, fig. 48).

Naturally there are several other techniques of twining – for example thrilling on the thigh, working with two or three persons, *etc.* – but this twining technique without any tool, only with the fingers, is suitable for every material, even short fibres like sheep-wool. When one strand or parts of it come to an end additional suitable material must be added, overlapping the ends by 1 or 2 cm; then twisting and crossing can be continued.

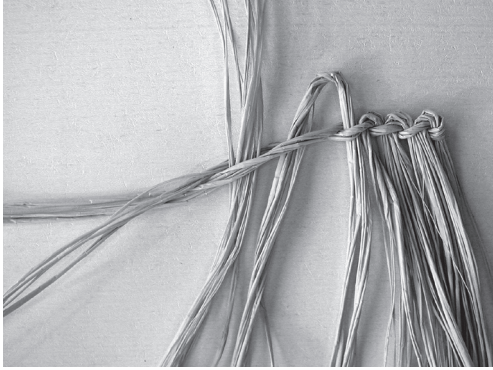


Figure 6.3. First row of weft-twining. Reconstruction and photo: Anne Reichert.

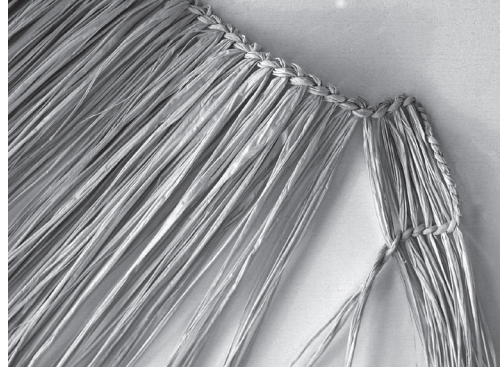


Figure 6.4. Weft-twining. Reconstruction and photo: Anne Reichert.

Twined fabrics

Weft-twining, plain-twining, two-strand twining, twined wicker weave, tied-twined basketry

One of the famous inventions of the Neolithic was the technique of weaving (Vogt 1937, 43). The exact shape of the loom is unknown, but there are many fragments of woven fabrics, mostly made from flax. There are also numerous fragments of twined fabrics, and they are made in so many different patterns that this technique must have had a very long tradition since Palaeolithic times.

As in Europe prehistoric plant textiles are preserved only under particular conditions, for example frozen in ice or in continuously wet sites, most finds date from Neolithic lake settlements or from wells.

The most frequently used material for weft- or plain-twining was bast, especially lime bast (Reichert 2000; 2005a). In contrast to weaving, for which a loom and spun or twisted threads are necessary, the plain-twining technique doesn't need any instrument – only the fingers – and can be performed directly with the raw material.

Analogous to the warp of a loom there are vertical strands, but in contrast to the weaving technique these strands must not be fixed. For the weaving only one thread is used for the weft. The plain-twining technique works with two horizontal elements at the same time.

The fibre bundles forming the warp must have more than twice the required length of the fabric. They are bent in the middle to form a 'U'. The two horizontal elements are used like twining a cord, but with each crossing a vertical element is fixed. If two vertical elements are taken together while twining, the starting border will be tighter (Figure 6.3).

When the border has the required width, the whole workpiece is turned and a cord is twined whose length corresponds to the distance to the next row. The hanging bundles are lightly twisted before being secured by the next weft row (Figure 6.4). This enhances the stability of the finished textile.



Figure 6.5. Weft-twined mat. Reconstruction and photo: Anne Reichert.

In this manner many fabrics were made in the Neolithic, for example the mat of the 'Man in the Ice' or 'Oetzi' (3350–3100 BC) discovered in 1991. The weft-twined fragments did not belong to a cloak like that shown in the published drawing (Egg and Spindler 1993, 88, fig. 36). For a cloak, in the second and third row from the top several strands must be separated into two bundles to widen the cloak at the shoulders (Reichert 2006b, 6, fig. 8). This, however, is not detectable on the original fragments of which additional parts had been found one year later, frozen to the stone where the man had lain (Lippert 1992, 251, fig. 8). According to Spindler (1994, 146), several cords had been knotted into the upper edge of the fabric "at regular intervals of 6 to 7 centimetres [...] whose function is unclear." Perhaps the mat (Figure 6.5) had not only been used as an isolation pad. Knotted together at the top with the cords, the man could have worn it as a long hood covering his head, his shoulders and his back (Figure 6.6). Similar mats, plaited in the same technique as the Neolithic mat, are used in Japan to the present day.

The little dagger-sheath in the Iceman's equipment is not the oldest that has been discovered, but the oldest completely preserved weft-twined item made from lime bast, whose function is quite clear. While being hacked out of the ice a pickaxe had damaged the dagger together with the sheath (Fleckinger 2003, 74).

Figure 6.7 shows the different stages of working the twined fabric. The upper border is fixed with two narrow rows. The distance of about 1.3 cm between each row is bridged by twined cords at both sides. Twining the last rows now and again two strands are



Figure 6.6. Possibly 'Oetzi' had worn his mat in this manner. Drawing: Katja Reichert.

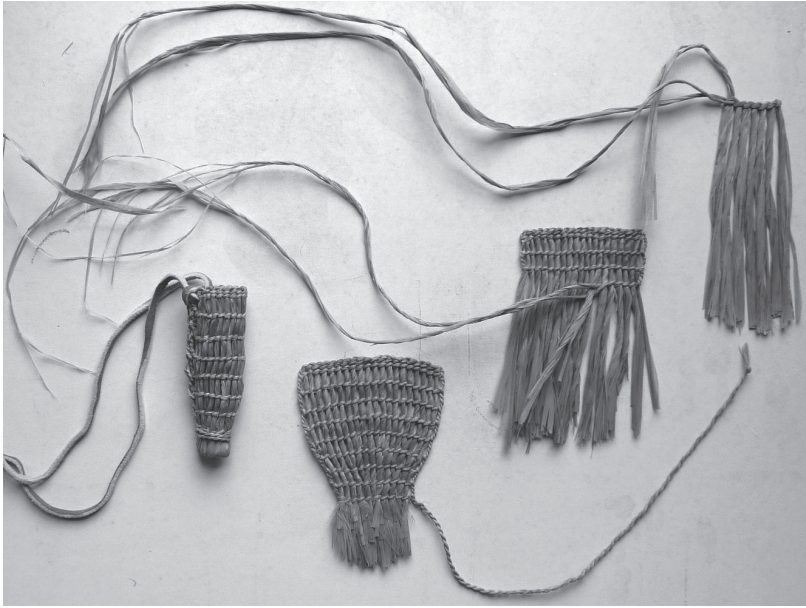


Figure 6.7. Phases of weft-twining a dagger-sheath from lime bast. Reconstruction and photo: Anne Reichert.

fixed together so that the fabric becomes narrower. The last hanging bast strips were bent to the inside of the sheath – a good upholstery for the sharp point of the dagger – and tied up. To finish the sheath both edges are sewn together with a twined cord of lime bast (Reichert 2001, 61–62, fig. 1–4).

Besides the weft-twined fabrics with fixed borders some were begun over a twined cord (Médard 2010, 75, fig. 54a–g) so that it was possible to narrow them. Different patterns are made by varying the distances between the horizontal rows or changing the direction of twining the rows (S respectively Z; Figure 6.8).

At Hornstaad, Lake Constance, Germany, a small piece of fabric made from lime bast had been found which shows a change in the direction of plain-twining (Feldtkeller and Schlichtherle 1998, 27). In this manner corners can be shaped. It is possible that the fragment was part of a box for carrying items, or a dress with sleeves. The horizontal and vertical stripes on the bodies of women depicted on slates from Gönnersdorf, Germany (about 10,500 BC), could be interpreted as representing clothing (Feldtkeller 2005, 24). The Neolithic fragment from Hornstaad (c. 3900 BC), however, is too small to reconstruct it correctly.

Another technique of weft-twining with holes is illustrated in the sketch of a find from Auvèrnièr, Lake Neuenburg, Switzerland (Egloff 1985, 85, fig. 8). In each horizontal row, the vertical warps are split into two halves. Each half is fixed together with half of the neighbouring warp, giving a zigzag pattern (Figure 6.9). Later this rectangular mesh is attached to a twig frame and then enlarged with coiled basketry of rushes and secured with lime bast strips (Reichert 2006a, 91–93). The sides of the sieve are made



Figure 6.8. Different patterns of weft-twining. Reconstruction and photo: Anne Reichert.

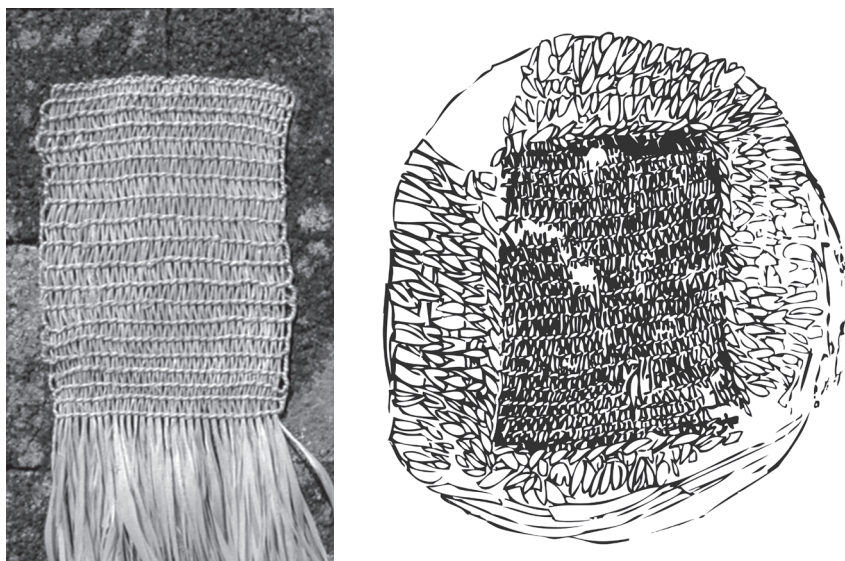


Figure 6.9. Weft-twined fabric with a zigzag pattern. Reconstruction and photo: Anne Reichert.

from bark. As it was not possible to find out the original type of the bark, I made experiments with different barks, e.g. linden-tree, cherry, pine. Birch bark was the most suitable (Figure 6.10).

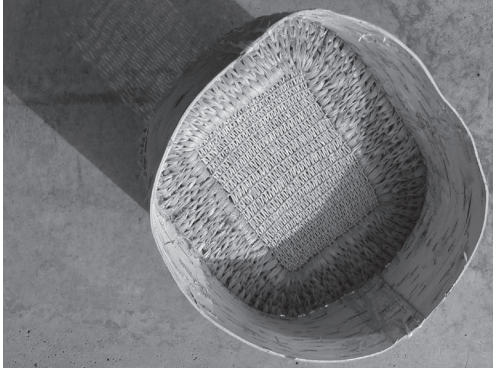


Figure 6.10. Reconstruction of the sieve from Auvernier. Reconstruction and photo: Anne Reichert.

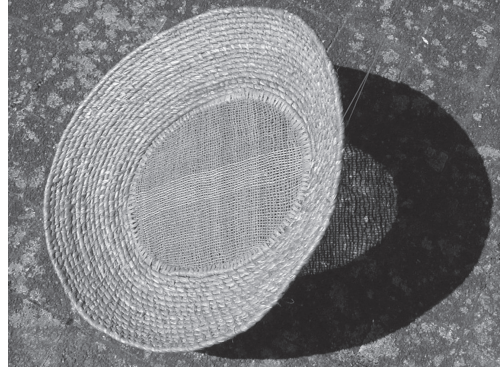


Figure 6.11. Reconstruction of the sieve from Hornstaad. Reconstruction and photo: Anne Reichert.

Weft-twined fabrics with twined or plaited threads

For the vertical elements sometimes twined or plaited threads are used instead of lightly twisted or straight bast strips. In several items even the horizontal elements are twined threads. In this manner, several sieves had been plaited (Körber-Grohne and Feldtkeller 1998, 175).

The bottom of a Neolithic sieve found at Hornstaad-Hörnle, Lake Constance, dating to c. 3900 BC (Schlichtherle 1990, 129, fig. 88), is made from twined threads of diameters from 0.8 to 1.4 cm both for the warp and the weft. The sieve mesh is sewn to a bent twig using lime bast strips. The side of the sieve is made in coiled basketry technique with bundles of rush, secured with lime bast strips. For reconstructing the sieve (Figure 6.11) about 64 hours were needed, mostly for twining the fine threads (Reichert 2006a, 87–91).

Several twined fabrics with plaited threads of different diameters for the vertical elements were found at the Neolithic settlements on the Lake Constance and the Swiss lakes. Also different types of weft-twined items are known, called weft-pile or ‘fur’ twining because of the bast bundles which hang down loosely on the outer surface and resemble fur. At Wangen, Lake Constance, dating to 3800–3600 BC (Feldtkeller and Schlichtherle 1998, 24), some pieces of weft-twined fabric were found, made of thin plaits with loosely hanging ends. The weft-twining is only visible on one side. The loosely hanging bast fibres cover the opposite side and give the fabric a ‘furry’ appearance (Figure 6.12). It may have been part of a garment.

Weft-twined fabrics with additional layers

From the Neolithic lake settlements weft-twined fabrics with two or more additional layers are also known. Several conical items with two different sides could have been hats (Bartel and Schönfeld 2005, 37, fig. 25; Egloff 1989, 67; Feldtkeller 2004, 59, fig. 5.1–6; Hafner and Suter 2004, 48, fig. 7; Rast 1990, 121, fig. 8). Hanging strips of lime bast cover the weft-twined fabric, for example the hat from Wangen-Hinterhorn, Lake



Figure 6.12. Weft-twined fabric made of thin plaits with loosely hanging ends. Reconstruction and photo: Anne Reichert.

Constance, dating to 3800–3600 BC (Feldtkeller and Schlichtherle 1987, 76, fig. 2.2). Beginning at the bottom, ‘U’-shaped lime bast bundles are laid around a twined cord and secured with a row of plain-twining. From the second row of plain-twining, 1.5 cm from the first, the fabric is worked all the way around. From the third row, 15 cm long hairpin-shaped bast bundles are fixed together with the vertical strands of the plain-twining (Figure 6.13). As the hat tapers to the apex, occasionally two bast strands are fixed together and partially cut off. At the top the remaining bast bundles are bent together and pass inside, where they are fixed with a twined cord. The weft twining can only be seen on the inside (Figure 6.14). The bast bundles, which hang down loosely on the outer surface, provide better protection from the rain since the water can run off the hanging strips, just like on a thatched roof.

Another Neolithic hat, found at Sipplingen, Lake Constance (c. 3300 BC), was started from the apex. In this case the bast bundles cannot be fixed while twining around but must be sewn on afterwards (Figure 6.15).

Quite another very complicated technique was used for the hat of Seekirch-Achwiesen, Federsee, dating to 2900–2600 BC (Feldtkeller 2004). Figures 6.16–6.18 show some steps of the reconstruction (Reichert 2006c, 14–16). Lime bast strands of about 40 cm length are fastened in the middle. One half is bundled into a ‘handle’, the other is spread out into bundles and twined all around from the centre. After five rounds, the strips of the ‘handle’ had been untied and fastened into the work with four more rows of weft-twining. Then ‘U’-shaped bast bundles are attached so that one half of a bundle is fixed together with one half of the next bundle (Figure 6.16). Tied weft-twined rows



Figure 6.13. From the third row hairpin-shaped bast bundles are worked into the twist bindings. Reconstruction and photo: Anne Reichert.



Figure 6.14. Reconstruction of the hat, found at Wangen. The weft-twining rows can only be seen on the inside of the hat. Reconstruction and photo: Anne Reichert.



Figure 6.15. The hat from Sipplingen, which is started from the apex, must have the bast bundles added afterwards. Reconstruction and photo: Anne Reichert.

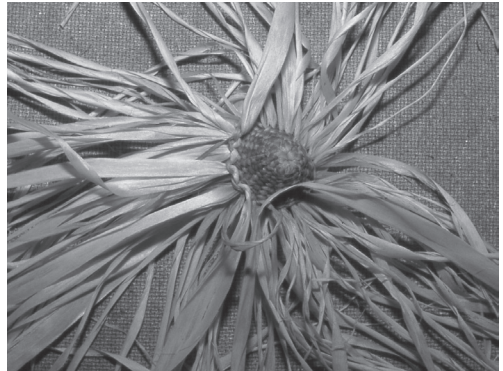


Figure 6.16. After several fine twined rows 'U'-shaped bast bundles are attached. Reconstruction and photo: Anne Reichert.

were covered with new bast bundles which are fixed together in the two following rows. The last five rows are again covered with hanging bast bundles (Figure 6.17). All twined rows can be seen only from the inside (Figure 6.18), on the outside they are mostly covered.

A 15 cm broad piece of weft-twined fabric with sewn on bast bundles was found at See-Mondsee, Austria (Antl-Weiser and Holzer 1995, 12, fig. 7). At Hornstaad-Hoernle, Lake Constance (c. 3900 BC), a relatively large piece of a plain-twining had been excavated, on which two layers of lime bast were knotted (Feldtkeller and Schlichtherle 1987, 78, fig. 4). It may have been part of a cloak. Similar cloaks had been worn in

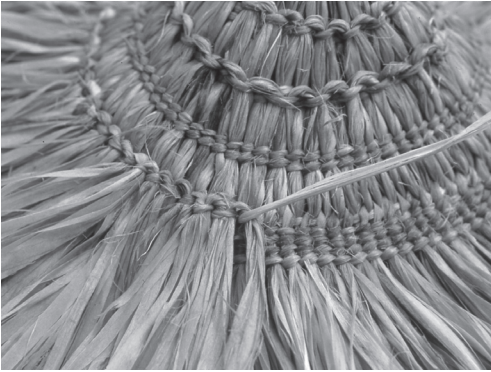


Figure 6.17. The last five rows are again covered with hanging bast bundles. Reconstruction and photo: Anne Reichert.

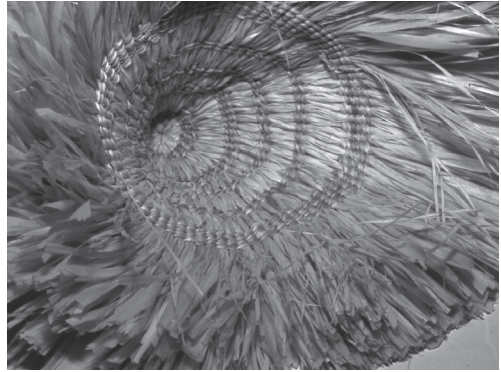


Figure 6.18. Reconstruction of the hat, found at Seekirch-Achwiesen. The twining rows can only be seen from the inside of the hat. Reconstruction and photo: Anne Reichert.



Figure 6.19. The weft-twined body of the cloak, made from lime bast. Reconstruction and photo: Anne Reichert.



Figure 6.20. To the second and the third row of the weft-twined body two layers of bast strips are knotted. Reconstruction and photo: Anne Reichert.

Germany until the beginning of the 20th century (Schuster 1993). For an archaeological exhibition the author had to dress the figure of a little boy and reconstructed this three-layered fragment. In the second and third rows from the top, each strand was separated into two bundles to widen the cloak at the shoulders (Figure 6.19). After the weft-twined body was finished two additional layers of lime bast, each fixed on a twined cord, were attached to the second and the third row of the main section (Figure 6.20). Experiments in wearing the cloak showed that it is warm and partially water-tight. The water runs off the outer layers of bast. However, in heavy prolonged rain the water will gradually work its way through the separate layers (Reichert 2006c, 17–18).

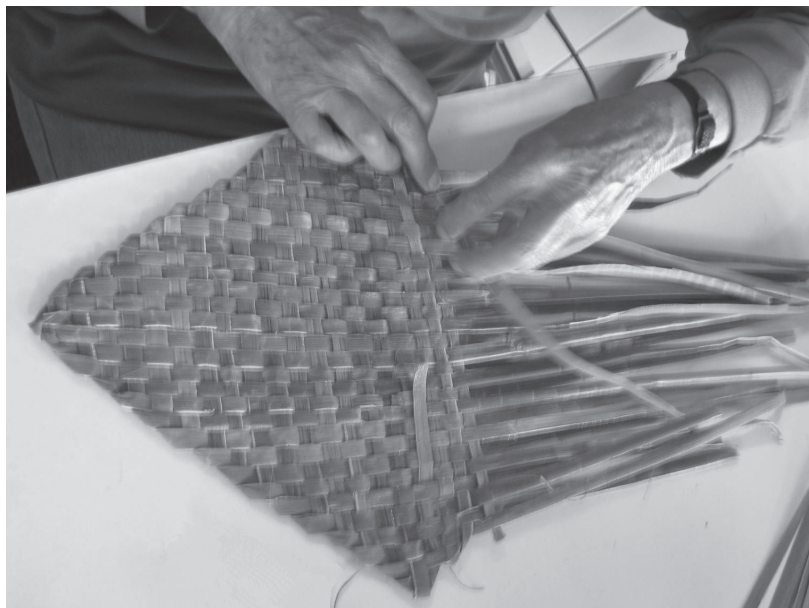


Figure 6.21. Diagonal plaiting with leaves of reedmace. Reconstruction and photo: Anne Reichert.

Weft-twined items with more than three layers, so-called pad fabrics, from Robenhausen, Switzerland, had been described by Vogt (1937, 32, fig. 52–54).

Plain-weave plaiting

Besides the many variations of weft-twined fabrics in the Stone Ages, plaited fabrics were also known. This technique corresponds to plain weaving in cloth. In both directions there is only one element in the material – compared to weft-twining where two horizontal elements are working. But in contrast to weaving no tool is necessary. The simplest form is called tabby and is produced by weft strips passing over and under alternate warp strips. Most of the Neolithic fragments are without edges, and it is not clear in which manner they are made: diagonal or right-angled.

For the diagonal plain-weave plaiting in Figure 6.21 leaves of reedmace were used. The little basket found at Sutz-Lattrigen, Lake Biel, Switzerland, dating to 3200–3100 BC (Hafner and Suter 2004, 47, fig. 4), is a right-angled plaiting from strips of lime bast. Figure 6.22 shows a reconstruction.

Tabby plaiting with thick lime bast strips was also used for the sandals found at Saint-Blaise, Lake Neuenburg, Switzerland (Egloff 1989, 67). Another Neolithic sandal, found at Allensbach, Lake Constance, dating to 3200–2800 BC (Feldtkeller and Schlichtherle 1987, 80, fig. 5), shows also a tabby plaiting, but it has two layers. Half-weave technique was used by the author for the reconstruction. Strips of lime bast for the warp are fixed

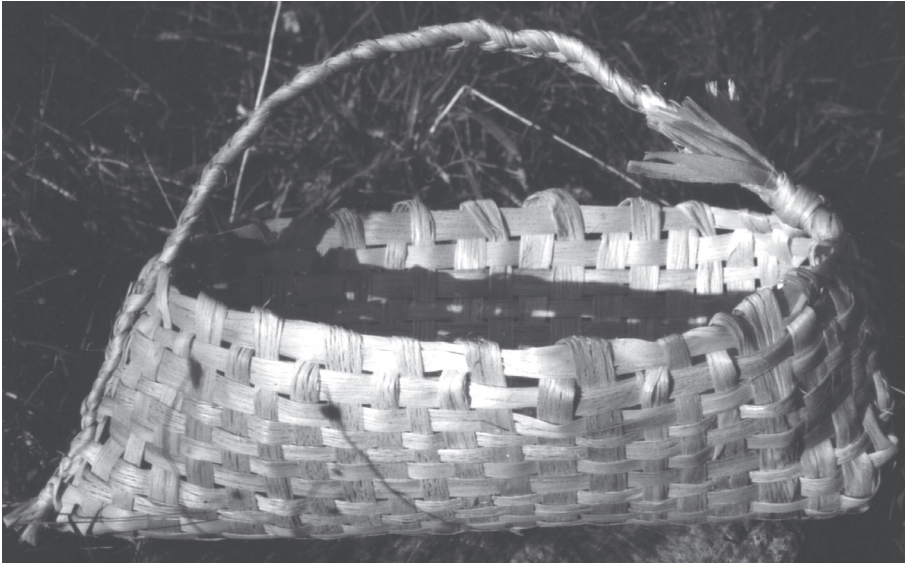


Figure 6.22. Reconstruction of the little basket, found at Sutz-Lattrigen, a right-angled plaiting with strips of lime bast. Reconstruction and photo: Anne Reichert.

to a rectangular frame. With a stick the natural interweave can be opened so that the horizontal element goes through in one step. In each following row the horizontal element must go up and down alternately (Figure 6.23). The finished mats are folded in the middle over a twined cord and later drawn together with this cord to form the toe of the sandal. The edges of the mats are sewn together with strips of lime bast. As the sandals are open at the heels (Figure 6.24), they must be fixed around the ankles with twined cords while walking.

A special type of weaving is called 'reps'. In this technique the material of the horizontal interweave is pushed close together so that the strips of the warp cannot be seen. A sandal found in 2008 at Sipplingen, Lake Constance, dating to 2900–2860 BC (Matuschik, Müller and Schlichtherle 2009, 47–48), is plaited in this manner as new analysis methods show

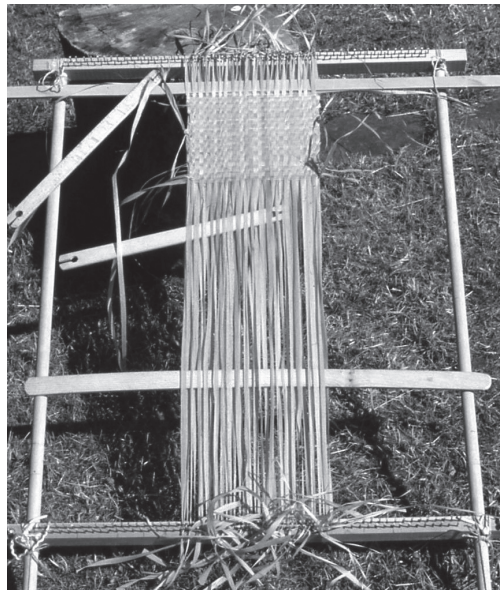


Figure 6.23. Half-weaving with strips of lime bast fixed to a frame. Reconstruction and photo: Anne Reichert.

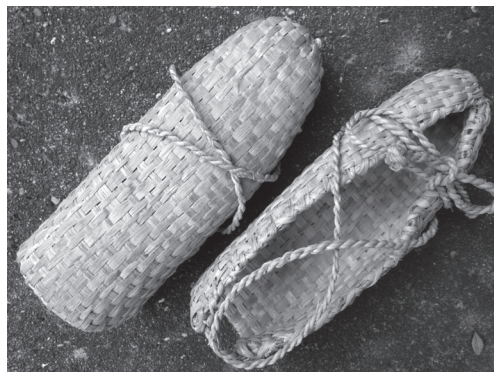
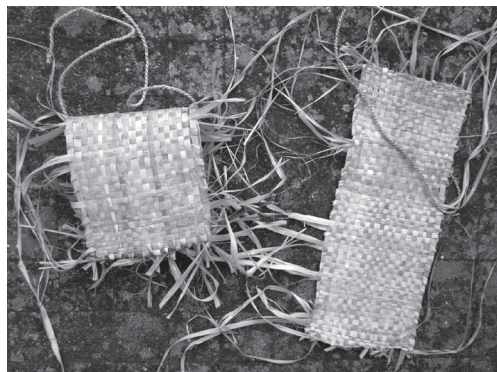


Figure 6.24. Reconstruction of the sandals Allensbach 2, made from lime bast. Reconstruction and photo: Anne Reichert.

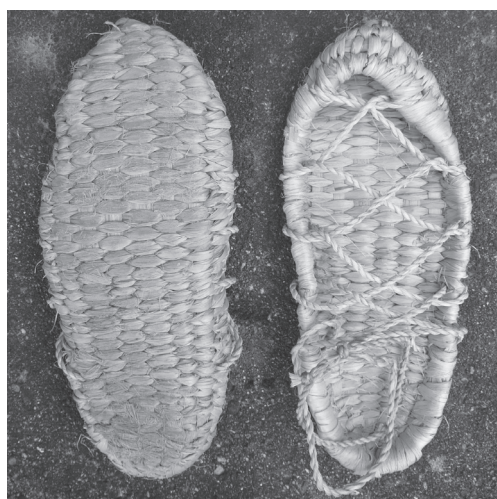


Figure 6.25. Reconstruction of the sandal find 2 from Sipplingen in reps technique, and the sole of the sandal after two hours walking. Reconstruction and photo: Anne Reichert.

(Wiesner and Beirowski, forthcoming, fig. 2). But it is difficult to push the strips of lime bast close together, they always tend to spread out. After walking in the sandal reconstruction for only two hours the sole under the heel was already showing signs of wear (Figure 6.25).

Compared to this reconstruction, sandals made in weft-twined technique are more durable. The author reconstructed sandal find 1 from Allensbach, Lake Constance, dating to 3200–2800 BC (Feldtkeller and Schlichtherle 1987, 82, fig. 7), using weft-twining (Reichert 2006c, 11 Fig. 9–11). These sandals were more durable because the lime bast strips were twisted before being twined – but according to new analysis methods this reconstruction is not correct. The original sandal Allensbach 1 is also made in reps technique.

Mats made in twill-plaiting technique were also found partly preserved as an impression on ceramic. This can be seen on a piece from Michelstetten, Lower Austria, c. 4300 BC (Grömer 2006, 187, fig. 13,1). Leaves of reed-mace which have fine grooves like the original impression were used for the reconstruction by the author. Experiments showed that such a clear impression could only arise when the clay had been worked on the mat (Figure 6.26). If a ceramic bowl is put on a mat only for drying, such a clear impression is impossible (Reichert 2010, 49).



Figure 6.26. Mat made in twill technique using the leaves of reedmace, and the imprint of this plaiting on a sheet of clay. Reconstruction and photo: Anne Reichert.

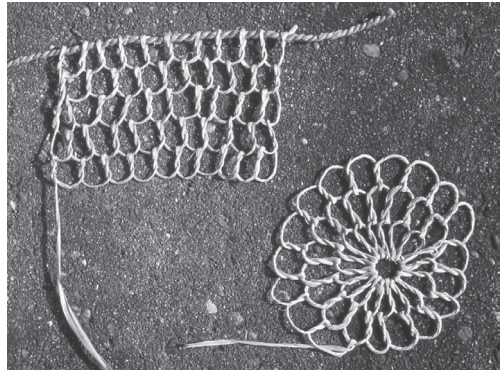


Figure 6.27. The double-twisted looping technique can be done rectangular or round. Reconstruction and photo: Anne Reichert.

Meshing – Making nets

Knotless nets have been known of since Mesolithic times (Gramsch 1999). The technique is called twisted looping or full-turn looping and can be done directly with the raw material, for example strips of willow bark or bast. This technique can be done with one looping only, but also with two or more loopings, and it is possible to fabricate both a rectangular or a round net (Figure 6.27).

Quite another technique for making nets is shown by a fragment from Mondsee, Austria (Antl-Weiser and Holzer 1995, 12, fig. 6). The nearly square meshes are made by a special technique of twining shown in Figure 6.28. A bast-strip is laid over a horizontal twined cord and twined as long as the width of the net should be. At a distance of about 5 cm from the first vertical cord another bast strip is laid with which 5 cm are twined. After that, one strand is twisted 5 cm long, laid around the first vertical cord, and twined back with itself until it meets with the second vertical cord. All further meshes of this row are made like this mesh. The next vertical row of meshes follows at 5 cm and is made in the same way. With this technique meshes of any size can be made.

It is possible that the net of 'Oetzi' had been made in the same way. Unfortunately it had been destroyed so badly while being hacked out of the ice that only many fragments

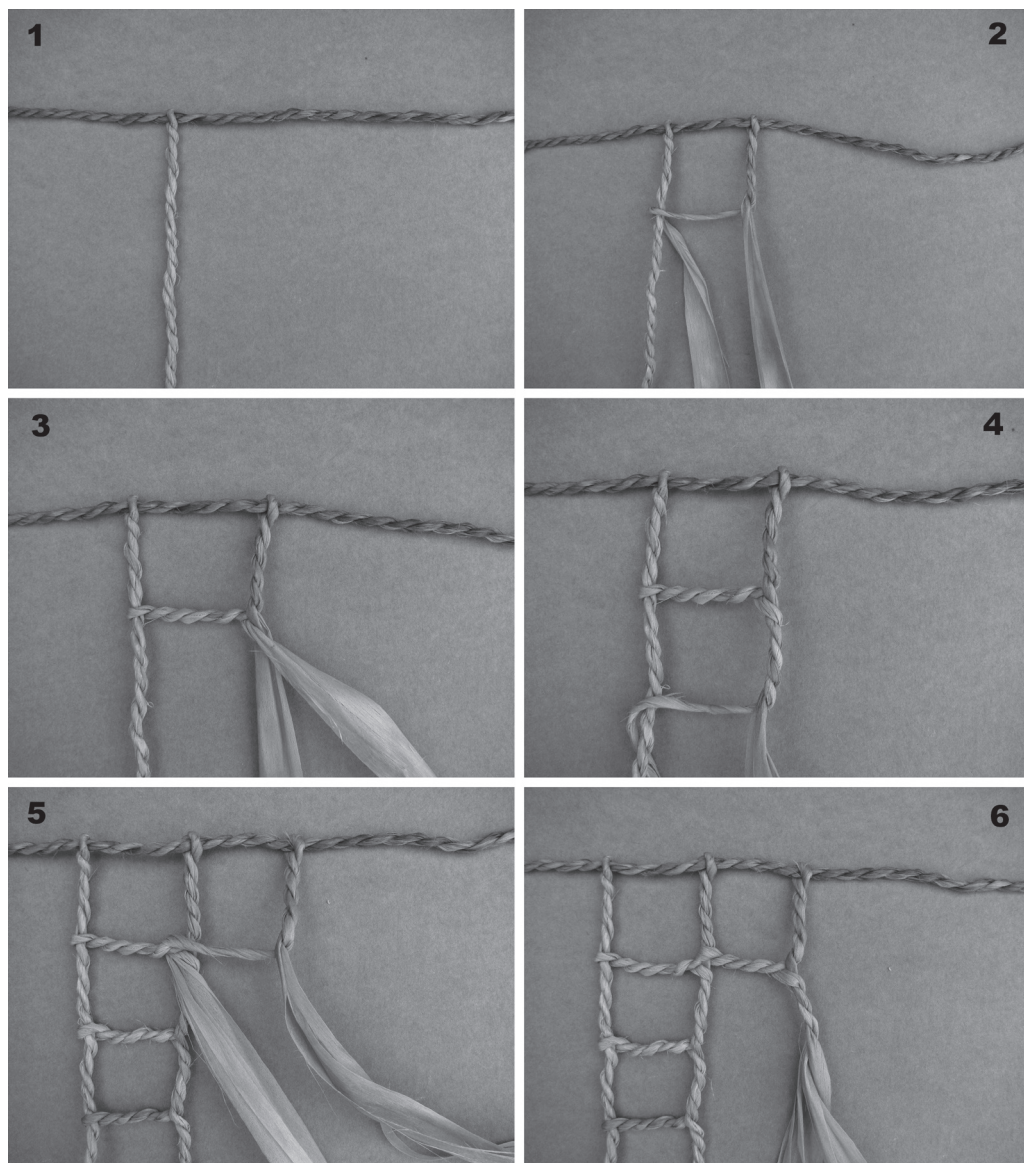


Figure 6.28. Knotless netting with lime bast strips. Reconstruction and photo: Anne Reichert.

of twined cords of lime bast are preserved (Fleckinger 2003, 85). It could have been used to catch birds or other small animals, or to carry grass from the alpine pastures down to the village (Figure 6.29). People in the mountains used similar nets up to the end of the last century.

Other Neolithic nets were made from spun or twined threads of flax. There are



Figure 6.29. Net used for transporting grass. Reconstruction and photo: Anne Reichert.

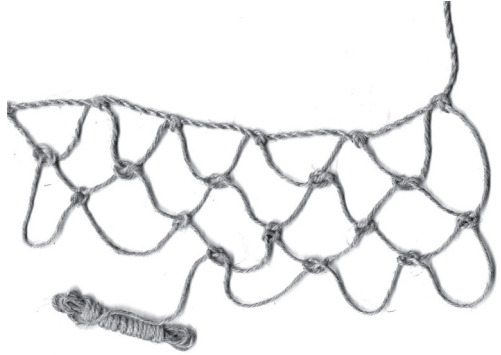


Figure 6.30. Making a net with overhand knots using a twined thread of flax. Reconstruction and photo: Anne Reichert.

different types of knots. Figure 6.30 shows the so-called overhand knot which was mostly used for fishing-nets (Ruoff 1981, 261, fig. 17).

A very special sort of net, made with twisted and twined cords, had been found in the three-layered shoes of the 'Iceman'. Figure 6.31 shows the remains of the right shoe and the inner net structure of the left shoe. It took a lot of time to reveal the method of producing these nets (Reichert 2000; 2005a; 2005b). The longitudinal twined cords of the net structure for the left and the right shoe are different. From a twined cord of lime bast (Pfeiffer and Oegg 2000) – not grass as was published first – 15 other cords of varying length are hanging (Figure 6.32). The ends at the bottom of the twined cords are fixed to the sole of bearskin by a 2 cm wide leather strap. A drawing of Goedecker-Ciolek (1993, 105, fig. 46) shows the cords rising in the middle of the strap, but this does not work. As the loops at the ends of the twined cords are very narrow, it is difficult to get the 2 cm wide strap through, and then the cords always slide to one side of the strap, in this case to the side next to the foot. As the uppers later are fixed to the sole through the same slits, but going up and down alternately (Figure 6.34), there is a 2 cm space available for the insulation layer. The longitudinal strings of the net for the left shoe are knotted together, going around with a twisted strip of lime bast. The strings of the right net are knotted together, beginning at the toe, going around the sole to the toe, and then going back in the same way, with a space to the first knotting row. The longer cords on the instep going to the toes show that the left net is worked to precisely follow the shape of the foot. The right net is open on the instep, and afterwards it is held together with the help of a twined shoe-lace over the top of the foot (Figure 6.33). The deerskin uppers are then fixed to the sole using the same slits as before, but with only a 0.5 cm thin leather strap. Then the space of 2 cm between the inner net structures and the uppers is filled with dry grass, a good isolation material. When the shoes (Figure 6.34) are worn, the strings of the nets are quickly compressed into the grass layer and are scarcely noticed. Three-layered shoes – High Tech of the Stone Age!



Figure 6.31. The remains of the right shoe of the 'Man in the Ice' and the inner net structure of the left shoe. © South Tyrol Museum of Archaeology Bolzano.

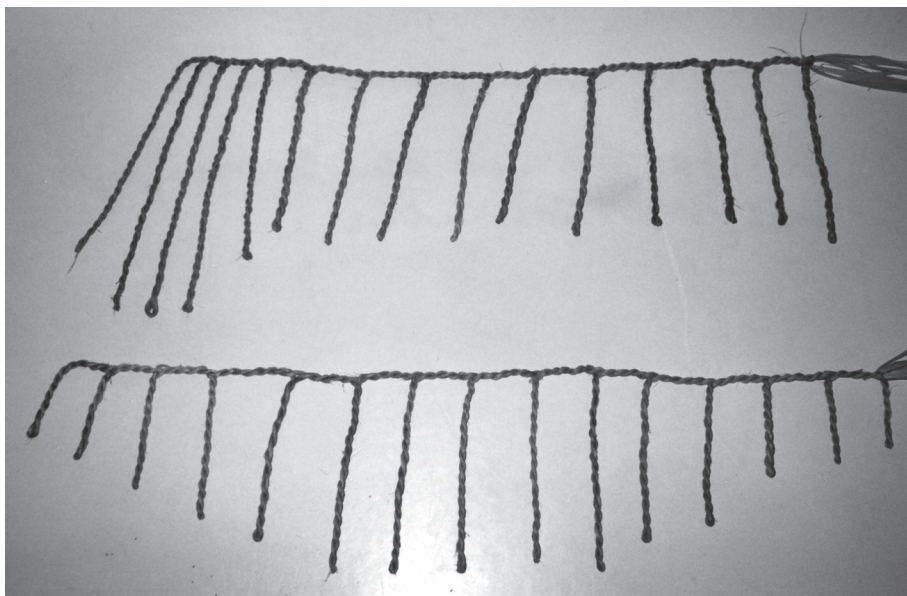


Figure 6.32. The longitudinal twined cords of the net structures for the left and the right shoes. Reconstruction and photo: Anne Reichert.

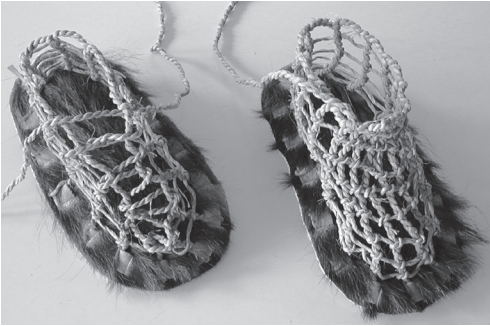


Figure 6.33. The inner net structures are secured to the bearshin soles with a 2 cm wide leather strap. Reconstruction and photo: Anne Reichert.



Figure 6.34. Reconstruction of 'Oetzi's' three-layered shoes. Reconstruction and photo: Anne Reichert.

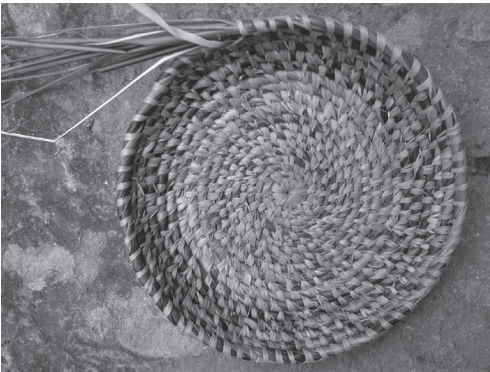


Figure 6.35. Coiled basketry made from junc and lime bast. Reconstruction and photo: Anne Reichert.

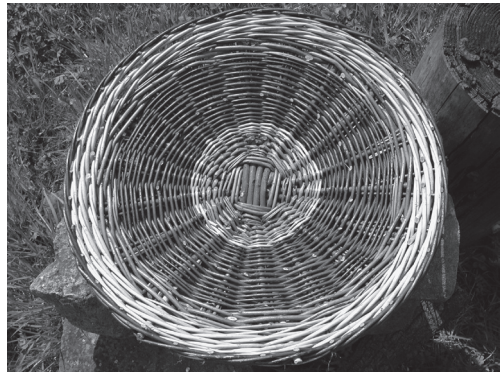


Figure 6.36. Basket made from peeled and unpeeled willow twigs. Reconstruction and photo: Anne Reichert.

Basketry

In the Neolithic the technique of coiled basketry was often used (Körber-Grohne and Feldtkeller 1998, 150). Several stems of rush, grass or other material are lightly twisted into a coil which is sewn securely to the previous coil using strips of bast. There are different methods to fix the coils: Either the bast strip goes around the coil (Figure 6.35), or the strip goes through the coil or through the former bast strip. Also several sorts of stitches can be used (Seiler-Baldinger 1991, 41).

Wickerwork with stakes and weaver was also known (Figure 6.36). Thin branches of willow, alder and hazel were the most often used material for this type of baskets in the Neolithic and Bronze Age (Rast-Eicher and Reinhard 1998, 289).



Figure 6.37. Warp-weighted loom, used for weaving experiments with spun threads of flax. Reconstruction and photo: Anne Reichert.

Weaving and spinning

From the Neolithic only small fragments of plain woven linen fabrics and the loom-weights are preserved (Ruoff 1981, 255). It is possible that the warp-weighted loom had a shape similar to that shown in Figure 6.37, used for weaving experiments by the author. Back and forward movement of the heddle rod, on which every second warp is fixed, opens the natural and the artificial sheds. To use a loom it is absolutely necessary to have spun or twined yarn both for the warp and the weft, while all the techniques shown above can be made directly from the raw material. From Neolithic times many little weights – so-called whorls – have remained, mostly made from ceramic (Ruoff 1981, 253). Fixed on a wooden stick they are used to spin fibres of wool (Figure 6.38), flax or nettle. But it is not possible to spin lime bast, grass, rushes or other similar material. Twining is the better – and much older – method to get threads, cords and ropes.



Figure 6.38. Spindle for spinning sheep wool, and whorls of ceramic. Reconstruction and photo: Anne Reichert.

References

- Antl-Weiser, W. and Holzer, V. (1995) Neue Ergebnisse der Pfahlbauforschung in Österreich. *Plattform, Zeitschrift des Vereins für Pfahlbau und Heimatkunde e. V.* 4/1995. Unteruhldingen 1995, 8–19.
- Bartel, A. and Schönfeld, G. (2005) Wetterfest und warm: Ein jungneolithischer Spitzhut aus Pestenacker. *Das archäologische Jahr in Bayern 2004*. Stuttgart 2005, 35–37.
- Capitani, A. de and Leuzinger, U. (1998) Arbon Bleiche 3. Siedlungsgeschichte, einheimische Traditionen und Fremdeinflüsse im Übergangsfeld zwischen Pfyn- und Horgener Kultur. *Jahrbuch der Schweizerischen Gesellschaft für Ur- und Frühgeschichte* 81, 1998, 237–249.
- Egg, M. and Spindler, K. (1993) Die Gletschermumie vom Ende der Steinzeit aus den Ötztaler Alpen. Vorbericht. Sonderdruck aus: *Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz* 39, 1992. Mainz 1993.
- Egloff, M. (1985) Le panier du cueilleur. Etapes de la vannerie préhistorique en Europe. Jagen und Sammeln. *Jahrbuch des Bernischen Historischen Museums 1983–1984*. Bern 1985, 81–87.
- Egloff, M. (1989) Des premiers chasseurs au début du christianisme. *Histoire du Pays de Neuchâtel, Tome 1. De la Préhistoire au Moyen Âge*. Hauterive 1989, 11–160.
- Feldtkeller, A. (2004) Die Textilien von Seekirch-Achwiesen. Ökonomischer und ökologischer Wandel am vorgeschichtlichen Federsee. *Hemmenhofener Skripte*. Freiburg i. Br. 2004, 56–70.
- Feldtkeller, A. (2005) Spuren der ersten Kleidung. *Archäologie in Deutschland* 1, 2005, 22–24.
- Feldtkeller, A. and Schlichtherle, H. (1987) Jungsteinzeitliche Kleidungsstücke aus Ufersiedlungen des Bodensees. *Archäologische Nachrichten aus Baden* 38/39. Freiburg i. Br. 1987, 74–84.
- Feldtkeller, A. and Schlichtherle, H. (1998) Flechten, Knüpfen und Weben in Pfahlbausiedlungen der Jungsteinzeit. *Archäologie in Deutschland* 1, 1998, 22–27.

- Fleckinger, A. (2003) *Oetzi, the Iceman*. Vienna/Bolzano 2003.
- Glory, A. (1958) Débris de corde paléolithique à la grotte de Lascaux (Dordogne). *Mémoires de la Société Préhistorique Française*, Tome 5. Paris 1958, 135–169.
- Goedecker-Ciolek, R. (1993) Zur Herstellungstechnik von Kleidung und Ausrüstungsgegenständen. In Die Gletschermumie vom Ende der Steinzeit aus den Ötztaler Alpen. Sonderdruck aus: *Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz* 39, 1992. Mainz 1993, 100–113.
- Gramsch, B. (1999) Baumbast und Holz. *Archäologie in Deutschland* 4, 1999, 20–21.
- Gramsch, B. (2002) Friesack: Letzte Jäger und Sammler in Brandenburg. *Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz* 47, 2000, Teil 1. Mainz 2002, 51–96, Tafel 1–6.
- Grömer, K. (2006) Vom Spinnen und Weben, Flechten und Zwirnen. Hinweise zur neolithischen Textiltechnik an österreichischen Fundstellen. *Archäologie Österreichs* 14–7, Sonderausgabe, 2003–2006, 171–188.
- Hafner, A. and Suter, P. J. (2004) *5000 Jahre. Abgetaucht – aufgetaucht. 1984–2004*. Archäologischer Dienst des Kantons Bern 2004.
- Kernchen, I. and Gramsch, B. (1989) Mesolithische Netz- und Seilreste von Friesack, Bezirk Potsdam, und ihre Konservierung. *Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam* 23, 1989, 23–28; 228–234, fig. 4–10.
- Körber-Grohne, U. and Feldtkeller, A. (1998) Pflanzliche Rohmaterialien und Herstellungstechniken der Gewebe, Netze, Geflechte sowie anderer Produkte aus den neolithischen Siedlungen Hornstaad, Wangen, Allensbach und Sipplingen am Bodensee. *Siedlungsarchäologie im Alpenvorland V*. Stuttgart 1998, 131–242.
- Lippert, A. (1992) Die erste archäologische Nachuntersuchung am Tisenjoch. In F. Höpfel, W. Platzer and K. Spindler (eds), *Der Mann im Eis, Band 1*. Innsbruck 1992, 245–253.
- Matuschik, I., Müller, A. and Schlichtherle, H. (2009) Besiedlungsgeschichte und -dynamik der jungsteinzeitlichen Pfahlbausiedlungen von Sipplingen ‘Osthafen’, Bodenseekreis. *Archäologische Ausgrabungen in Baden-Württemberg* 2008. Stuttgart 2009, 45–49.
- Médard, F. (2010) *L’art du tissage au Néolithique IVe–IIIe millénaires avant J.-C. en Suisse*. CNRS Editions, Paris 2010.
- Pfeiffer, K. and Oeggl, K. (2000) Analysis of the bast used by the Iceman as binding material. In S. Bortenschlager and K. Oeggl (eds), *The Iceman and his Natural Environment. Palaeobotanical Results. The Man in the Ice, Vol. 4*. Wien/New York 2000, 69–76.
- Rast, A. (1990) *Die Verarbeitung von Bast*. In Die ersten Bauern, Band 1. Pfahlbaufunde Europas. Forschungsberichte zur Ausstellung im Schweizerischen Landesmuseum. Zürich 1990, 119–122.
- Rast-Eicher, A. and Reinhard, J. (1998) Gewebe und Geflechte. Textile et vannerie. In S. Hochuli, U. Niffeler and V. Rychner (eds), *Die Schweiz vom Paläolithikum bis zum frühen Mittelalter. SPM III Bronzezeit*. Basel 1998, 285–290.
- Reichert, A. (2000) Rotten oder Rösten von Lindenbast? *AEAS Anzeiger* 2000, 5–7. www.aeas-gaes.ch
- Reichert, A. (2000); (2005) *Zur Rekonstruktion der ‘Ötzi’-Schuhe*. Experimentelle Archäologie, Bilanz 1999. Oldenburg 2000, 69–76. *Experimentelle Archäologie in Europa, Sonderband 1*. Oldenburg 2005, 255–262.
- Reichert, A. (2001) Zwirngeflechte in der Ausrüstung des Gletschermannes. Zur Herstellungstechnik der Dolchscheide, des Umhangs und der Innengeflechte der Schuhe. Experimentelle Archäologie im 3. Jahrtausend n. Chr., Internationale Fachtagung der Arbeitsgruppe für Experimentelle Archäologie in der Schweiz, ETH Zürich, 1998. *Zeitschrift für Schweizerische Archäologie und Kunstgeschichte* 58, 1/2001, 61–66.
- Reichert, A. (2005a) Be- und Verarbeiten von Lindenbast. *AEAS Anzeiger* 2005, 5–7. www.aeas-gaes.ch

- Reichert, A. (2005b) Ötzi-Schuhe – High Tech der Steinzeit. *AEAS Anzeiger* 2005, 8–9. www.aeas-gaes.ch
- Reichert, A. (2006a) Zur Rekonstruktion neolithischer und bronzezeitlicher Siebgeflechte. *Experimentelle Archäologie in Europa, Bilanz 2005*. Oldenburg 2006, 87–94.
- Reichert, A. (2006b) Umhang oder Matte? Versuche zur Rekonstruktion des Grasgeflechts des ‘Mannes aus dem Eis’. *Waffen- und Kostümkunde. Zeitschrift für Waffen- und Kleidungsgeschichte*, Heft 1, 2006, 1–16.
- Reichert, A. (2006c) Von Kopf bis Fuß – gut behütet und beschuht in der Steinzeit. Rekonstruktion von neolithischer Kopf- und Fußbekleidung und Trageversuche. *Experimentelle Archäologie in Europa, Bilanz 2006*. Oldenburg 2006, 7–23.
- Reichert, A. (2007) Zwischen Rinde und Holz: Bast – textiles Material der Steinzeit. In *Holz-Kultur. Von der Urzeit bis in die Zukunft*. Wissenschaftlicher Begleitband zur gleichnamigen Sonderausstellung 4. Februar–28. Mai 2007 im Landesmuseum für Natur und Mensch Oldenburg. Mainz 2007, 203–230.
- Reichert, A. (2010) Neolithische Textilfragmente und Rekonstruktionsversuche – mit Beispielen aus Österreich. *Archäologie Österreichs* 21/1, 2010, 42–50.
- Ruoff, E. (1981) Stein- und bronzezeitliche Textilfunde aus dem Kanton Zürich. *helvetia archaeologica* 12/1981, 45/48, 252–264.
- Schlichtherle, H. (1990) *Siedlungsarchäologie im Alpenvorland I. Die Sondagen 1973–1978 in den Ufersiedlungen Hornstaad-Hörnle I*. Stuttgart 1990.
- Schuster, H.-J. (1993) *Von Dienstboten, Tagelöhnern, Hütekindern und Landarbeitern. Lebens- und Arbeitswelt der ländlichen Unterschichten*. Freilichtmuseum Neuhausen ob Eck. Kleine Schriften 10, 1993.
- Seiler-Baldinger, A. (1991) *Systematik der Textilen Techniken*. Basler Beiträge zur Ethnologie, Band 32. Basel 1991.
- Spindler, K. (1994) *The Man in the Ice*. London 1994.
- Vogt, E. (1937) *Geflechte und Gewebe der Steinzeit*. Monographien zur Ur- und Frühgeschichte der Schweiz. Basel 1937.
- White, R. (1986). *Dark Caves, Bright Visions. Life in Ice Age Europe*. The American Museum of Natural History, New York/London 1986.
- Wiesner, I. and Beirowski, J. (forthcoming). *A Neolithic Shoe from Sipplingen – Technological Examination and Conservation*. Proceedings of 11th ICOM-CC WOAM WG Conference in Greenville (NC) 2010.

Tracing Production Processes and Craft Culture: the reconstruction of the Gunnister Man costume

Martin Ciszuk and Lena Hammarlund

In 1951 a body of a man, dated to around 1700, was found in a peat bog at Gunnister, Shetland Islands, Great Britain. The man had been wearing a shirt, breeches, a coat and a jacket made of fulled wool fabrics. His stockings, gloves, two caps and a small purse were knitted from wool yarn. Following a partnership agreement between Shetland Amenity Trust and National Museums Scotland, detailed studies were undertaken on all of the artifacts with the intention of making a full set of replicas.

The project included documentation at the museum in Edinburgh and was performed in a close co-operation between participants having different specialisms, deep knowledge of craft, and experience from the reconstruction of historical and archaeological textiles. The practical work of the reconstruction was carried out as close to the originals as possible. It included the complete production process, from fibre selection to the finished garments.

The aim of this project was wider than to create an exhibit. The combination of thorough analyses and practical work created the basis for interpretations of production processes. This experience based knowledge also generates keys to the understanding of 'craft culture' which includes both tools and organization of work.

Introduction

In 1951, two men digging peat near Gunnister, in north Shetland, UK, discovered woollen clothing and other objects. The remains were laid out like a burial, and the woollen clothing was well preserved, but only fragments of the man remained. He wore a shirt (museum number NA 1039), a coat (NA 1038), breeches (NA 1040), and a jacket (NA 1037) made of fulled wool fabrics. His stockings (NA 1043), a pair of gloves (NA 1044), two caps (NA 1041–2) and a small purse (NA 1045) were knitted from wool yarn.

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A bundle of woollen yarns were found in his pocket. His purse contained one Swedish (C9678) and two Dutch coins (C9668, C9666) minted between 1681 and 1690, which dated his death to around 1700. The finds went to the National Museum of Antiquities in Edinburgh (Henshall and Maxwell 1954, 30–42).

During the planning of the new Shetland Museum and Archives in 2006, a project was developed to make a reconstruction of the Gunnister finds for permanent display. Following a partnership agreement between Shetland Amenity Trust and National Museums Scotland, detailed studies were undertaken on the artefacts. Dr. Carol Christiansen, curator at Shetland Museum, was head of the project. Lena Hammarlund, craftsperson and textile researcher in Gothenburg, Sweden, was given the task to spin, weave, and full the fabrics. Martin Ciszuk, of the School of Textiles, University of Borås, Sweden, has done the cutting and hand sewing of the garments.

The reconstruction project started with documentation at the museum in Edinburgh and was performed in a close co-operation between the participants, each having different specialisms, deep knowledge of craft, and experience from the reconstruction of historical and archaeological textiles. Detailed notes and photographs were made and patterns were drawn of each garment. This collected information formed the base for the practical reconstruction work. The aim of the project was wider than creating an exhibit. The combination of thorough analyses and practical work created the basis for interpretations of production processes. This experience-based knowledge also generated keys to the understanding of 'craft culture' which includes the choice of materials, working methods and organisation of work (Christiansen and Hammarlund forthcoming; Ciszuk and Hammarlund forthcoming).

This article will focus on the woven garments and include fibres, yarns, weaving, and finishing of the fabrics as well as pattern layout, sewing and distressing of the clothing.

Description of the original garments

The shirt (Figure 7.1) was much worn and had been heavily mended. It was 87 cm long with a deep front opening closed with round buttons made of felted wool covered with the same fabric as the shirt. The shirt had a low standing collar and gussets in the side seams below the waist. The sleeves were made from two curved pieces and have vents at the wrist closed with buttons. The shirt was sewn with an unpigmented, 2-ply wool yarn and the sewing is regular and carefully made.

The shirt was discoloured by the peat to a yellowish-brown colour, but was originally made from unpigmented wool. The fabric was a fulled 2/2 twill (2/2 twill is a weave based on a unit of four warps and four wefts, in which each weft passes over two adjacent warps and under the next two. The binding points are set over by one warp on successive wefts, and form diagonal lines). Because of excessive wear, the felted fibres on the surface were worn off in most places. The original fabric had numerous weaving faults and was unevenly woven with variations in warp and weft spacing. The shirt front and back are made from loom-widths, as selvages can be seen in the side seams, and the fabric varied between 48 and 53 cm in width. There was a difference in overall length between the left and right sides of up to 7 to 8 cm. This can be seen on the back of the shirt, where the tailor created a fold (Figure 7.2).

Patches were inserted in the armholes and the left sleeve was repaired by adding a



Figure 7.1. The shirt. Photo: courtesy of National Museums Scotland.



Figure 7.2. The fold in the back of the shirt made to compensate for the uneven shrinking of the original fabric. Photo: Carol Christiansen.

<i>Thread</i>	<i>Yarn Twist Direction</i>	<i>Yarn Diameter</i>	<i>Yarn Twist Angle</i>	<i>Even/Uneven Spinning</i>	<i>Thread Count in Fabric</i>
shirt, warp	z	0.5–0.7 mm	45°	uneven	12–14/cm
shirt, weft	s	0.8–1.0 mm	35°	uneven	8–10/cm
patch, warp	z	0.7–0.8 mm	45°	even	8–10/cm
patch, weft	s	0.8 mm	30–35°	even	8/cm

Figure 7.3. Yarns and thread density in the shirt and patches.



Figure 7.4. The coat. Photo: Carol Christiansen.

facing at the wrist made of the same fabric. This patch fabric was made in a 2/2 twill, in a lightly pigmented, coarser wool than the shirt. The patching was skilfully made with regular stitches, using a 2-ply wool thread. Mending in several places of the shirt indicates long and heavy use. These have been made with at least two different wool yarns and without much care or skill. A wool yarn was used to replace a missing button at the wrist. The yarns and thread density are shown in Figure 7.3.

The coat and breeches (Figure 7.4 and Figure 7.5) are made of the same fabric and are without patches or mending. The coat is 99 cm long. It is cut in four pieces with seams in the sides and centre back, with wide flaring skirts and a high vent in centre back. On the front there are pockets decorated with buttons. The sleeves are relatively wide with large cuffs folded back. The coat has no collar and closes in front with round buttons. The breeches are of knee length, 57 cm, with wide legs, gathered to a waistband and closed with a single button in the front.

The coat and breeches were originally greyish, but now have a brownish tone. The



Figure 7.5. The breeches. Photo: Carol Christiansen.

Thread	Yarn Twist Direction	Yarn Diameter	Yarn Twist Angle	Even/Uneven Spinning	Thread Count in Fabric
warp	s	0.7–1.0 mm	30–35°	even	8–8.5/cm
weft	s	0.7–1.0 mm	30–35°	even	8–8.5/cm

Figure 7.6. Yarns and thread density in the coat and breeches.

fulled fabric was made in 2/2 twill; the weave can only be seen where the fabric is worn. The weaving and fulling is very regular. The preserved selvages give a fabric width between 60 and 62 cm. The garments were sewn with 2-ply wool yarn in the same colour as the fabric, and the sewing is regular and carefully made.

The garments are altered; on the coat the cuffs are folded down to increase sleeve length and on the breeches two pleats are made in the waistband to decrease the width. The yarn and thread density in the coat and breeches is shown in Figure 7.6.

The jacket (Figure 7.7) has kept its original brown colour with brown patches on both sleeves. It has a lining made in different reused fabrics in brown and now yellowish brown, including knitted pieces of fabric. The jacket is extremely worn, and has been mended in several stages. The lower parts of the sleeves are like rags and there is a big hole in the back. The jacket is 72 cm long. The body is fitted with flaring skirts and vents in the sides and centre back. It has a standing collar and was buttoned in centre front with round buttons. The curved sleeves are buttoned at the wrist.

The brown jacket fabric as well as the brown lining seems to be composed of mostly brown pigmented fibres, giving the original brown colour. In the yellowish brown lining no pigmented fibres are detected, indicating an originally white fabric. The woven fabrics were made in 2/2 twill with a distinct twill appearance. The brown jacket



Figure 7.7. The jacket. Photo: Martin Ciszuk.



Figure 7.8. The lining of the jacket is made from different reused fabrics. Photo: Carol Christiansen.

fabric and the brown lining were originally fullered. The light lining shows no traces of felting because of the extreme wear. As far as can be seen, the fabrics appear well made and no weaving faults were recorded. The fabric width can be estimated to 60 cm. The garments were sewn with 2-ply brown wool yarn, and the sewing is regular and carefully made (Figure 7.8).

The jacket was patched at both elbows and it seems that the same fabric as in the

<i>Thread</i>	<i>Yarn Twist Direction</i>	<i>Yarn Diameter</i>	<i>Yarn Twist Angle</i>	<i>Even/Uneven Spinning</i>	<i>Thread Count in Fabric</i>
jacket, warp	z	0.5–0.7 mm	45°	even	11–12/cm
jacket, weft	s	0.8–1.2 mm	30–35°	even	8–9/cm
brown lining and elbow patch, warp	z	0.5–0.7 mm	45°	even	14–15/cm
brown lining and elbow patch, weft	s	0.7–1.0 mm	30–35°	even	10/cm
light lining, weft	z	0.5–0.6 mm	35°	even	14–15/cm
light lining, weft	s	0.7–0.8 mm	35°	even	10/cm

Figure 7.9. Yarns and thread density in the jacket.

brown lining was used. There is mending both on the face side and in the lining of the jacket. The mending was coarsely made with several different wool yarns. Two different coarse yarns were used to close the jacket where buttons were missing. The density of the yarns and thread in the jacket are shown in Figure 7.9.

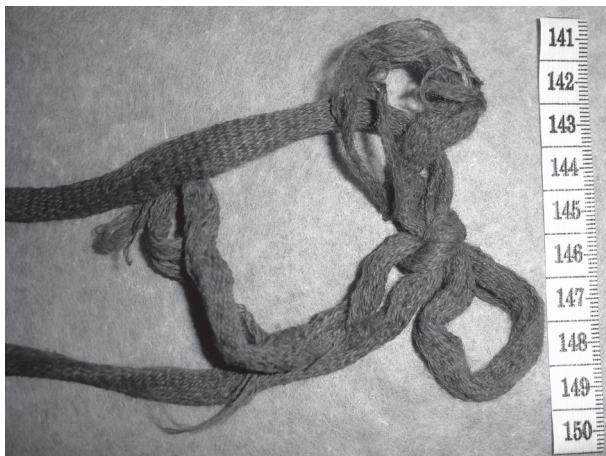
The band (Figure 7.10) was woven in two colours, originally white and probably light greyish brown as one of the yarns is unpigmented and the other is lightly pigmented. The band is woven in warp-faced tabby (tabby is a weave based on a unit of two warps and two wefts, in which each weft passes over one and under one warp). It has a warp colour effect pattern, with horizontal small stripes, with a counter change half way across (see Henshall and Maxwell 1954, 35). It is about 2 cm in width and the length is about 85 cm, excluding much worn fringes at both ends. The band is nicely made. The yarns and thread density in the band are shown in Figure 7.11.

A yellowish brown woven patch was sewn to one of the stockings (Figure 7.12). It is a very thick, weft-faced tabby. The warp consists of tripled single yarns, made in a mix of light and dark wool, probably originally greyish in colour. The weft was spun from unpigmented wool. The fabric does not appear to have been fullled, and this has contributed to the significant unravelling at the raw edges where the patch is sewn to the stocking. The yarns and thread density in the woven stocking patch are shown in Figure 7.13.

Discussion about the craft based on the reconstruction work

The practical work of the reconstruction was carried out as close to the originals as possible. It included the complete production process, from fibre selection to the finished garments. Similar materials, historic tools and processes, which could have been used on the originals, were used in the reconstruction, as long as this was possible and feasible. Based on the assumption that the original clothing was locally made, the intention was that the wool should be sourced in Shetland, and non-Shetland wool should only be used where local wool types could not give a satisfactory result.

Figure 7.10. The band, probably a garter tied in a bow. Photo: Carol Christiansen.



Thread	Yarn Twist Direction	Yarn Diameter	Yarn Twist Angle	Even/Uneven Spinning	Thread Count in Fabric
warp	zz-S	0.5–0.6 mm	30°	even	23/cm
weft	s	0.7	?	?	4–5/cm

Figure 7.11. Yarns and thread density in the band.

Figure 7.12. The left stocking foot with a patch made from a reused fabric, probably a blanket. Photo: Carol Christiansen.



Thread	Yarn Twist Direction	Yarn Diameter	Yarn Twist Angle	Even/Uneven Spinning	Thread Count in Fabric
warp	z	0.5–1.0 mm	45°	uneven	3 x 2.5–3/cm
weft	ss-Z	2–3 mm	25–30°	even	7–8/cm

Figure 7.13. Yarns and thread density in the woven stocking patch.

Fibres

The fibre composition varies in the different garments. Deliberate choices have apparently been made to give the garments appropriate properties for their use. The shirt fabric was made of unpigmented wool of a fine to medium-fine quality. The fibres appear rather soft and slightly woolly and would not be prickly, if worn directly against the body. The coat and breeches show a different fibre composition than the shirt. It is a mix of shorter, finer and coarser pigmented fibres, but finer unpigmented fibres are also present. In the fibre mix, dark and chalk white kemp fibres can be detected. The fibre composition gives a coarse appearance and handle and generates a durable fabric. In the jacket all the fabrics show a similar fibre composition that includes both coarser, longer outer hair and finer, softer underwool. The fibres in the brown fabrics appear rather even in colour, indicating that wool from brown fleeces has been used. The fibres in the light lining are unpigmented. The fibres used for the woven fabrics in the jacket give a coarse appearance and handle to the fabric, similar to the coat and breeches.

For the fabrics used for garments that show traces of being fulled, the felted surface textures indicate that fibres with good felting ability were chosen. This became apparent in the fulling of the woven samples, where different fibre qualities generated very different appearances.

In the band, the warp yarns consist of fine underwool and finer and coarser hair fibres, of which the hair fibres seem to predominate. In the light yarn no pigmented fibres were detected. The darker yarn consists of lightly pigmented fibres. This fibre mix has been used to spin a strong yarn. The fibre quality in the weft could not be determined, because it was concealed by the warp. In the stocking patch the warp was made in a mix of fine, light coloured underwool and light and dark hair fibres. The weft was made of unpigmented wool, which consisted of a fine underwool with possible fine hair mixed in. This fibre mix is the precondition for spinning a soft and woolly weft yarn.

Yarns

From the analyses of the yarns in the original clothing and during work with the reconstruction, further information about the craft process could be obtained. For the woven fabrics in 2/2 twill, single yarns were spun for warp and weft. The warp had the necessary amount of twist, so as not to break during weaving. Some of the weft yarns were spun with looser twist compared to the warp. This made them quicker to spin and gave a less hard handle to the fabric. However, the twist in the weft yarns had to be high enough to be suitable for fulling to the desired qualities, where too loose twist would create disadvantages like too high shrinking or a too woolly surface.

The shirt fabric, including the patches, and the three woven fabrics in the jacket had z-twisted warp and s-twisted weft. The coat and breeches differ, with s-twisted yarns in both warp and weft. In the band, 2-ply yarns (zz-S) were spun with hard twist for the warp. This gives the extra strength needed for this warp, which had to be handled rather 'brutally' when woven in tightly warp-faced tabby. The weft in the band is s-twisted. In the weft-faced tabby fabric used for the stocking patch, the warp was spun with z-twist. The 2-ply yarn (ss-Z) used in the weft shows bulkiness despite the

hard twist. Bulkiness also can be obtained by choosing wool with high crimp, such as underwool, which the fibres in this yarn indicate.

The yarns are evenly spun, except for the warp and weft in the shirt and the warp in the woven stocking patch. The uneven yarns should not be considered as a sign of low quality of craftsmanship. In the shirt the irregularities would be concealed by the felting, and in the stocking patch the warp would not be seen because it is covered by the weft.

When looking at the different yarns used in Gunnister Man's clothing it can be concluded that the warp yarns were mostly spun with z-twist. When a 2-ply yarn was used in warp the single yarns were also spun with z twist and then plied S. In the same way the weft yarns are spun with s-twist, and when a 2-ply weft yarn was used it was spun ss-Z. The only exception is the coat and breeches, with s-twisted yarns in both warp and weft.

Fabrics

For the woven fabrics in the shirt, coat, breeches and jacket, 2/2 twill weave has been used. In this weave two warp threads are lifted together. This minimises the risk of the warp threads clinging together, which may cause thread breaks and long floats during weaving. This phenomenon became very obvious when weaving the samples for the shirt: two different warp densities were tested to find the best for the fabric. With 11 threads per cm in the warp, only a few warp threads broke, while with 12 threads per cm problems with broken warp threads appeared very quickly. The weave, floating over two threads, makes the fabric more easy to full compared with a fabric in similar firmness woven in 2/1 twill or tabby. The 2/2 twill weave makes a firm fabric more flexible and gives it a better drape compared with 2/1 twill or tabby. It also adds more bulk to the fabric, making it warmer.

The shirt fabric is the softest of the 2/2 twill fabrics and comparable in softness with the stocking-patch. The fabric for the coat and breeches is more durable compared to the shirt, depending on the fibre quality and its thickness. The fabric has a good drape and gives a thick and heavy impression without being stiff and compact. The jacket fabric is more durable than the fabrics in the coat and breeches; this is due to the fibre quality containing longer hair fibres, but also the harder twist in the warp yarn, and a denser warp than weft sett.

The other weave that has been used is tabby. The wool band is made in warp-faced tabby and the warp is 2-ply, with a hard twist. These two factors give a band that will be very strong, though the yarn is rather fine. The band's fineness gives a good pliability, making it easy to knot, suggesting its use as a belt or a garter. The warp density is a precondition for the colour pattern.

The fabric used for one stocking patch is made in weft-faced tabby. The soft, bulky weft yarn, combined with the loosely beaten weft-faced tabby, gives this fabric a soft handle and good insulating properties. A suggestion is that this patch may have come from a worn-out blanket, which has been carefully made at each stage of manufacture to obtain the best properties for its original function as possible.

Finishing treatments

When a fabric is taken off the loom it needs some kind of finishing treatment to even out tension and, if necessary, to make it less hard or stiff. In a fulling process both shrinking and felting of the wool fibres takes place. This increases the fabric's density and makes it thicker and stronger. It also increases the fabric's resistance to wear and tear and it becomes warmer and more wind- and waterproof.

Some of the fabrics from the Gunnister Man's clothing still show traces of being fulled. In the shirt fabric the fulling seems to be unevenly made, but this could be due to uneven weaving, with denser and more open areas in the fabric, resulting in uneven shrinking. The fulling has increased the softness, as fibres on the surface make it woolly. The coat and breeches are very evenly fulled, showing that the fullers had a good knowledge about the process. Without fulling this fabric would not have its good drape, nor would it protect so well against cold, rain and wind. This is also valid for both the brown fabrics used in the jacket. From the present state of the white lining in the jacket it was not possible to tell if it had been fulled. However, the suggestion was that it had been fulled to some extent to make the fabric denser. This suggestion was confirmed by the test samples. The current thread density in the lining would have been very hard to achieve on the loom and would then have resulted in a very hard and stiff fabric.

The band is so densely woven that there is no need for any fulling, maybe only washing to make it a bit less stiff. Fulling would result in felting of the fibres and the small-scale colour pattern would then not be distinguishable. The fabric in the woven stocking patch was not fulled, as this would have resulted in an extremely thick and stiff fabric, ruining the intended properties in the fabric construction.

Cutting and tailoring

The cut and construction of the Gunnister Man's clothing were apparently made by professional tailors, who followed a number of rules and habits. The choices made by the craftsmen can be traced in the details of the original garments. They also became evident in the reconstruction, where effort was made to follow both working methods and the order of working operations observed in the originals.

The cut of the body of the shirt is based on the straight loom widths. Extra width was added below the waist by inserting triangular gussets, a method of shaping garments with roots in the medieval period (Kania 2010, 139–143). The other garments differ from this; they are made from shaped pieces where the form of the garments is achieved by oblique or curved seams, and where there are straight joins in the pieces where the width of the fabric was not enough. The width of the fabrics could be measured to 48–53 cm for the shirt, and 60–62 cm for the coat and breeches; for the three jacket fabrics it was estimated to about 60 cm.

A 2/2 twill fabric displays different direction of the twill diagonal on either side. It is clear that the side with the twill diagonal in Z direction was chosen to be the face side when the garments were cut out. All main pieces of the pattern were laid out on the fabric with the warp running vertically in the garments. It is only in the small parts used for piecing that this was not always followed.

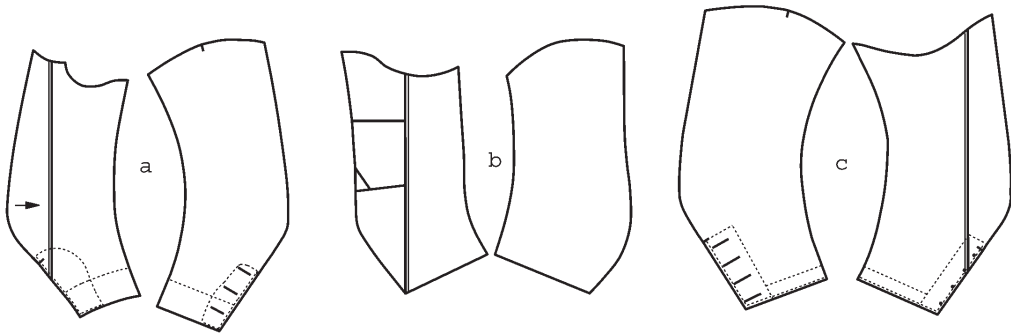


Figure 7.14. Cutting pattern of the sleeves of shirt, coat and jacket. Note the joins in the under sleeve on all garments. Drawing: Martin Ciszuk.

The pattern layout on the fabric was precisely made to use the material in the most economical way. By irregular joins and small differences in the shape of left and right sides of the garments, it is clear that most of the pieces were cut with the pattern laid out on a single layer of fabric. The major pieces, such as the body of the garments and the upper sleeves and cuffs, were cut first; the remaining off-cuts were then used to piece together the minor parts. The pieced parts were carefully placed where they would be less visible, like in the under sleeves, the under cuffs and in the sides of the skirts. The under sleeve is pieced in the same way in the shirt, the jacket as well as the coat (Figure 7.14). This indicates that all garments were cut by tailors who followed the same method for laying out the pattern on the fabric, even if the fabric width was not the same, by first cutting the upper sleeves and then piecing the under sleeve together from the leftovers of the fabric. The buttons and facings were also made from leftover pieces. The facings were cut using off-cut pieces with a selvedge. They are all sewn by overcasting the open edge, because a folded edge would be too clumsy, whereas the selvedge makes a strong and neat outer edge.

The lining of the jacket was made from different reused garments in various colours; the lining was apparently not intended to show. The rules for cutting were not followed, probably in order to use the already shaped pieces in the best way. Some parts of the lining were cut with the warp running horizontally, and some parts were used with the reverse side out. However, care was taken not to cut any part on the bias, which would have distorted the shape of the lining.

All the seams in the garments were made with hard spun 2-ply wool sewing thread. This yarn was apparently made specifically for sewing, because the twist direction, *zz-S*, is different from the yarns used for the patching, mending as well as for the knitting. The use of wool thread is probably connected to the local supply of raw materials. Linen or silk sewing thread was traditionally mostly used by tailors in Europe (Aneer 2009, 230; Rasmussen 2008, 178). However, in the North Atlantic area the climate restricted cultivation of flax, which made linen thread expensive and hard to access. The relatively coarse sewing thread, compared to modern ones, was suitable for the fulled fabrics. It was strong and generated almost invisible seams, because it was made in the same

colour and material as the fabrics. The sewing of the reconstruction demonstrated the connection between fabric thickness, sewing thread diameter and the length and spacing of the stitches in the different seams. Working with the correct materials generated the same number of stitches per cm in the reconstruction as in the originals.

A range of different stitches and construction methods were used in the garments. This represents the functional diversity of the seams and the materials used, but also a set of rules and traditions of how to construct garments. In the shirt and in many parts of the jacket the sewing is made in a variant of a flat fell seam; the pieces are joined from the face side with slanting stitches over a folded edge, and the seam allowances are then folded and stitched to the reverse, overcasting the raw edge.

In the coat and breeches, which are made of a thicker fabric, this seam would be very clumsy; it is only used in the crotch seam of the breeches. Other methods, which would generate flat seams, are used instead: where two selvages are joined they are overcast together from the reverse, in other cases two straight pieces might be joined with an overlap seam overcast from both face and reverse. Where strong and flat seams were needed, as in side seams, shoulder seams and armholes, the pieces were joined with back stitches sewn from the inside, the seam allowances were then separated and stitched down with running stitches. In other places, as the under sleeve seam and the skirts of the coat, a seam was made using back stitches from the inside, but leaving the seam allowances unfinished, making the seam less flat and stiff.

The lower edge of shirt, jacket and coat is a raw edge without a hem; the felting of the fabrics keeps the edges from unravelling. A sewn hem would have been too bulky and would have distorted the curving line of the skirts. The breeches, however, have a straight hem where the fabric is folded once and stitched to the reverse with overcast stitches. This hem helps to hold out the legs and interacts with the cut to give the breeches their wide shape.

The shirt and jacket have been patched and mended several times. The patching was made using a wool yarn with a twist direction, ss-Z, different than the sewing thread the garments were sewn with. Later, holes and torn seams were repaired with rough stitches in different kinds of coarse yarn, also spun ss-Z. Some of these correspond to the bundle of yarns, which were found in the man's pocket. This is also the case for the yarns that were used to replace missing buttons on the shirt and jacket, and to sew the patches on the stockings.

The coat and breeches have been altered, indicating that they were not originally made for the Gunnister Man. The cuffs of the coat were folded down to increase the arm length by about 7 cm. On the breeches the waistband was folded at both sides, reducing the width of the waist by about 15 cm; the folds were held together with rough stitches in a coarse, light yarn similar to the mending of the jacket.

Distressing

It was decided that the reconstruction should reflect the costume as worn by the Gunnister Man just before his death. To achieve this, the finished garments were washed and dried while wearing them to get a correct shape. Wear was simulated by shaving smaller and larger areas with a razor, removing the fibres on the surface. In places where there were holes in the originals the shaving was continued until the fabric broke. Several seams were torn and some of them crudely repaired as in the original



Figure 7.15. Distressing the reconstructed garments. Washing and felting was done in hot water and green soap. Photo: Viktoria Holmqvist.



Figure 7.16. Distressing the reconstructed garments. Seams were torn and repaired. Photo: Lena Hammarlund.

garments. This process was time-consuming and much more strenuous than expected because of the extremely strong fabrics and seams.

Conclusion

The analyses and reconstruction of the clothes of the Gunnister Man covers the whole chain of production, starting with fibre and ending with the finished garments including wear, patching and mending. This holistic working method has generated a deep understanding of the craft.

Different kinds of wool qualities from breeds of the North Atlantic region and England were tested in the reconstruction work. This leads to the conclusion that the

woven fabrics could have been made from wool from the primitive Shetland sheep or similar breeds in the North Atlantic area. These breeds have a fleece that consists of softer, crimpy underwool together with coarser, longer, straighter outer hair and some kemp (Christiansen, 2004, 11–17).

The wool was first sorted. In the jacket, parts of fleeces with underwool and long outer hair were used, which will give a strong fabric, while in the coat and breeches the parts containing underwool, short hair fibres and kemp have been selected. The fibres could then be separated. In the shirt and the stocking patch the long outer hair was probably removed by hand or by combing and the soft underwool was used, while in the band and the sewing threads most of the underwool has been removed and the long outer hair was used.

Yarns with specific properties were spun for different purposes. Twist direction is an intriguing topic. As a single factor in the construction of a fabric the direction of twist does not have a major influence on the final product (Hammarlund, forthcoming). It is rather connected to a tradition where there was a preference of spinning yarns with z-twist intended for warp and yarns with s-twist for the weft. This tradition might explain why z-twist has been used as the base for sewing threads (zz-S), because it was associated with strong warp yarns. In a similar way the knitting yarns (ss-Z) have s-twist in analogy with the looser spun weft yarns.

The fabrics in Gunnister Man's costume are not unique. Instead, they represent a production of fulled wool fabrics, vadmél, developed during a long period. The fabrics' construction and finishing treatment bear witness to good handicraft knowledge. Household production of vadmél in Shetland continued at least until the mid 17th century and was important as a resource for paying taxes and rents (Christiansen 2001, 189). Narrow loom widths are characteristic of cottage industry and household production, in contrary to broadcloth, which was produced by specialised workshops.



Figure 7.17. The reconstructed costume on display 2009 in Shetland Museum, Lerwick. Photo: Carol Christiansen.

The warp-weighted loom might have been used for the shirt, because of the irregular warp spacing, but for the other fabrics it is impossible to say on what loom they were produced.

The cutting and tailoring of the garments bear clear traces of being made by tailors working in a strong craft tradition. The uniform choices of face side of the fabric, methods of laying out the pattern, a particular sewing thread, and functional seams and stitches are all examples of this.

There is a difference between how sewing, patching and mending have been made, including the various sewing threads and yarns. This supports the interpretation that the garments were cut and sewn by a tailor, that the patching was made by a person skilled in sewing, but that someone without sewing skill made the coarse mending. Maybe this was done by Gunnister Man himself, as some mending is made with yarns like those found in his pocket.

As the twist direction is the same in the mending yarns and the knitted garments, the assumption could be made that the mending was done in a context with access to knitting yarn. This would fit well with the theory that there was a shift in textile production in Shetland at the end of the 17th century from weaving to knitting (Christiansen 2001, 217–220).

The garments were apparently used for a long time, being heavily worn and mended. The distressing of the reconstruction, which was made to imitate wear and tear, showed clearly how strong and durable the fabrics were (Figures 7.15–7.16). The coat and breeches were altered to fit a wearer for whom they were not originally made. These facts demonstrate the great value of garments and textiles before mass production.

This article illustrates how much information about craft culture can be obtained from objects. By evaluating their properties through analysis, experiments and reconstruction, researchers with craft knowledge can extract and illuminate the great knowledge, experience and labour that have been put into all steps of the production processes (Figure 7.17).

References

- Aneer, C. (2009) *Skrädderi för kungligt bruk: tillverkning av kläder vid det svenska hovet ca 1600–1635*. Acta Universitatis Upsaliensis, Diss Uppsala: Uppsala Universitet.
- Christiansen, C. A. (2001) *Primitive Wool and Early Textile Production in Shetland*. Unpublished thesis, University of Manchester.
- Christiansen, C. A. (2004) A Reanalysis of Fleece Evolution Studies. In *NESAT VIII*, Acta Archaeologica Lodziensia Nr 50/1. Łódź.
- Christiansen, C. A. and Hammarlund, L. (forthcoming) The Gunnister Man Project, I: The wools and knitting. In *NESAT XI*. The North European Symposium for Archaeological Textiles, May 2011, Esslingen.
- Ciszek, M. and Hammarlund, L. (forthcoming) The Gunnister Man Project, II: Weaving, cutting, sewing, and finishing. In *NESAT XI*. The North European Symposium for Archaeological Textiles, May 2011, Esslingen.
- Hammarlund, L. (forthcoming) The making of a fabric. In U. Mannering and M. Gleba (eds), *Designed for Life and Death*, National Museum of Denmark.
- Henshall, A. S. and Maxwell, S. (1954) Clothing and other articles from a late 17th-century grave at Gunnister, Shetland. *Proceedings of the Society of Antiquaries Scotland*. 86.

- Kania, K. (2010) *Kleidung im Mittelalter: Materialien – Konstruktion – Nähtechnik: ein Handbuch*. Köln: Böhlau.
- Rasmussen, P. (2010) *Skräddaren, sömmerskan och modet: arbetsmetoder och arbetsdelning i tillverkningen av kvinnlig dräkt 1770–1830*. Diss. Uppsala, Uppsala Universitet.

Reconstructing the Dyeing Industry of Pompeii through Experimental Archaeology: the challenges and rewards of a new approach

Heather Hopkins

Previous understanding of the scale of manufacture of Pompeii's textiles industry relied on theoretical assumptions applied to superficial measurements of surviving apparatus. This study was the first to realise that to understand the apparatus it was necessary to construct and use a replica. From the practicalities of construction to the ever-changing questions, the novelty of the situation presented both physical and theoretical challenges. Overcoming these led to a far broader foundation to the answer than was originally envisaged. The originally theoretical question is now grounded in experimental archaeology and engineering principles and the dyeing industry has been demonstrated to be far smaller than previously thought.

To determine the scale of manufacture of the city of Pompeii would allow an understanding of its economic significance and its place in the Roman world. Pompeii, at the foot of the Mount Vesuvius, was destroyed by a volcanic eruption on August 24th 79 AD. The destruction was swift and absolute: the pumice encased the buildings to the first storey, then the pyroclastic event removed and obliterated anything above this layer. What remained was encased in solid rock. Pompeii was a city frozen in time. Although a large number of the population had fled, taking artefacts with them, the industrial apparatus remained *in situ*, in the workshops within the city that they served. Pompeii therefore offers a unique opportunity to reconstruct the industries of a city, to determine the scale of manufacture and the place of the city in providing for itself, in exporting and in its place in the wider economic framework of the Empire.

Seventeen years prior to the volcanic eruption, an earthquake had levelled parts of the city and caused the aqueduct to cease functioning. The magnitude of the event and the aftermath caused great change within the city. Laws were passed allowing the city to take uninherited property. As the residential areas were the first to be reconnected to the water supply it was in the interest of businesses to move there. This led to the

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establishment of dyeing workshops in former residences and other properties that ordinarily would not have been industrial. The city returned to a functioning way of life, then seventeen years later was destroyed, and encapsulated, through the volcanic eruption. The city remained undiscovered until c. 1750 AD, when it was first noted as a source of arts, treasures and materials to be plundered. Only during the 19th and 20th centuries did archaeological exploration begin in earnest.

The dyeing industry is of interest in reconstructing the scale of manufacture of Pompeii because it is the only industry whose apparatus may be unambiguously identified. A *fullonicae* (fullery) had multiple uses: it did not just full cloth but was also what modern parlance would term a laundrette. Also, the dyeing apparatus have survived relatively intact and *in situ*. They are each in the context of the workshop in which they would have operated, in context of each other and in context of the city that they supplied. Therefore when calculating their production capacity, any more than the city would have required could have been exported, any less and the city would have relied on imports.

Prior to the current study the understanding of the scale of manufacture of Pompeii's textile industry relied on theoretical assumptions applied to superficial measurements of surviving apparatus. Moeller undertook a survey of the apparatus and concluded that the industry had been large enough to export (Moeller 1976), a conclusion that was questioned at the time (Wilde 1977). Jongman, using Moeller's data, concluded that the industry had been far smaller and that Pompeii relied on imports (Jongman 1988). Subsequent studies agreed with Jongman's conclusion that the industry was smaller than Moeller originally thought, but each relied on Moeller's data and did not collect their own (e.g. Laurence 1994; Mann 1994). The studies were purely theoretical and did not attempt to recreate the process involved or a physical understanding of the apparatus. The realisation that formed the basis of this study, that to determine the output of an industry it was necessary to understand the apparatus involved and that to do this it was necessary to construct and use a replica, was entirely new. While there have been craft reproductions of dyed textile and analysis of the archaeological examples, there has been very little study of the method of production and until this study there had been no full scale or practical replication of Roman dyeing apparatus. The closest reconstructed apparatus was the cooking vessel of the 16th century Mary Rose, the flag ship of Henry VIII (Mary Rose Trust 2001). This was a copper kettle with a lead flange placed in a brick brazier, reconstructed for public instruction and entertainment.

To construct and use an apparatus allows an understanding of not just how the apparatus operates, but also how a dyer would actually operate it. Using an apparatus allows an understanding of the cycle time: the time taken for heating, dyeing and cooling. Through this, fuel type and the quantity required can be calculated. A physical replica and its use allows an ergonomic assessment of the apparatus to be made. But the most important question was the design itself: no dyeing apparatus had survived absolutely and so the understanding of the 'design' was an overlapping composite. It was necessary to construct a replica to test the viability of the design. Through this any missing parts or amendments to the remains could be identified and the effect of choice of the materials used in the construction could be assessed. Measurements and

photographs had been taken of dyeing apparatus in a preliminary study in 1994 and these were combined to allow the construction of a replica apparatus (Janaway and Robinson, unpublished).

Design factors

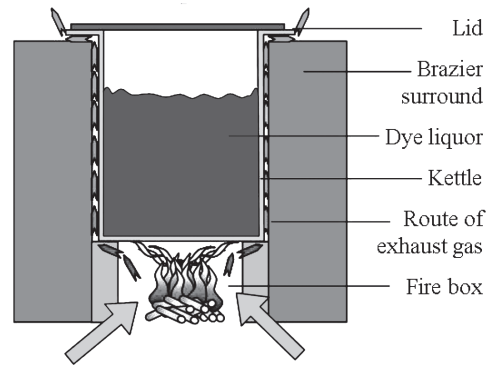
The location of a reconstruction is of the utmost importance to its success. This presented an unusual logistical challenge. To construct a replica that involves dyes and a fire would suggest a rural or otherwise distant, inaccessible location from an academic campus. This created transportation difficulties as the author and the majority of the volunteers could not drive. It was necessary to find a location somewhere close to the university. Sadly this was within a 'smokeless zone', which posed a problem when using a fire. Luckily, the study took place at the University of Bradford, and construction of the project took place in the inner-city on university-owned land in 2001–2. This coincided with the Bradford riots, when parts of the city were burned to the ground and a small, controlled academic fire that did not disrupt air quality or traffic did not excite comment (Figure 8.1).

After location, the next important consideration is the design and materials to be used. The apparatus was a replica of dyeing apparatus 5 in property VII ii 11 and apparatus 5 in property VII xiv 17 in Pompeii, data of which had been recorded in a preliminary survey in 1994 (Janaway and Robinson, unpublished). The choice of materials proved more problematic. The original materials used in Pompeii, a lead kettle and lime mortar, were banned through health and safety restrictions. Substitution was necessary, but the question was what would be suitable. As Reynolds stated, to use different materials in the construction of a replica renders it an experience, not an experiment (Reynolds 1999).

To determine the fuel used in heating the dyeing apparatus and the time taken, the materials used had to react in the same way as the originals: they should warm and the heat should pass through them the same way as the original materials used. Stainless steel was chosen to replace lead as the



Figure 8.1. Location of apparatus: in the midst of university halls, Astroturf and nature reserve, central Bradford. Author: left. Co-builder: right.



*Figure 8.2. Reconstructed apparatus.
Above: Pompeii apparatus 5, property
I viii 19. Top right: Replica apparatus.
Right: Schematic of apparatus*

thermal conductivity of lead is 35 W/mK while stainless steel is 27 W/mK (Callister 2000). In context, aluminium is 235 W/mK, so it may be seen that lead and stainless steel are seen as equivalents. The brick used had the same thermal conductivity as the brick, rubble and mortar used in the original apparatus. The replica was constructed as a full-size, full-scale and thermal match (Figure 8.2). There was no requirement that the materials provide an aesthetic match.

A criticism levelled at the reconstruction was that although it was possible to construct a replica it would not be possible to replicate a Roman to use it. The problem was deeper, as skeletal measurements do not give the full data about the physical abilities of the person in life. What was required was an ergonomic dataset that overlapped both the Roman skeletons and modern representatives that could be witnessed using the replica. By a quirk of history, the populations of Herculaneum (Capasso 2001) and Pompeii (Ciarello and Carollis 1999) coincided in size with the population of the United States between 1900–1960 (Hopkins 2007). During this time the armed services and automotive

manufacturers were designing equipment for an increasingly divergent population and so diligently recorded contemporary ergonomic data. The library of the University of Bradford holds such datasets, as it was founded in 1966 and specialises in automotive engineering. The author is the same height of an average Roman male (1.64 m, 5 ft 4) and the co-builder of the replica was within 0.02m of the height of the average Roman female (1.54 m, 5 ft 6). Both constructed and used the replica (Figure 8.1).

The next consideration was the recipe and the raw materials to be used. These were identified through a literary review of contemporary and historic writing, depictions, archaeological artefacts and the analysis from archaeological finds (Hopkins 2007). Madder and alum were the most commonly surviving dye and mordant used in the Roman world. This was fortuitous as both are used as food additives and so are deemed 'safe' to use in experiments. Accordingly, the recipe was chosen for dyeing with madder, pre-mordanted with alum. Historically, recipes have been a closely guarded secret and so even contemporary writings such as Pliny's *Natural History* are unreliable; he may have been given an incomplete or incorrect recipe on the assumption that he would not try to use it, or to prevent his success if he did. Few recipes remain, and those that do may not be widely available: for example it has been reported that there are no contemporary Greek recipes (Monaghan 2001) and yet several are reported by Lagercrantz (1913) in German and the original Greek. Modern recipes may also be problematic. At least six recipes for madder dyeing with alum that required pre-industrial equipment were examined and these differed from 'simmer for an hour' to 'boil for six hours and leave overnight' for the same step (Rosetti 1548; Brunello 1973; Storey 1978; Ponting 1980; Dalby 1985; Grierson 1986; Grieve 1992; Edmonds pers. comm. 1999). These recipes were dissected and examined. Although the times stated in the recipes differed, the changes that were intended to be caused at each stage were the same. The recipes were combined to provide a single one that would allow each change to take place in the shortest or most reasonable time. This was tested through laboratory work in 1999 (Hopkins, unpublished; Hopkins 2007). The closest original recipe was that of Storey (Storey 1978, 67).

The most commonly used material for textile in the Roman world was wool (Hopkins 2007). Analysis has shown that the Iron Age British sheep was the equivalent of the modern Soay and that the different shades of its wool were used as an under-colour in dyeing to produce different colours from the same dye (Ryder and Stephenson 1968; Ryder 1990). The Roman method was different and the sheep was equivalent to the modern Shetland, a larger sheep with a 2 kg white fleece that could be dyed any colour (Ryder 1990). Acquiring unwashed wool fleeces may appear to be problematic when based within the centre of a city. However, the University of Bradford is located on the same road as the National Wool Board's storage depot for the North of England, who kindly donated a fleece to the study.

When dyeing, a copious amount of water is required. Dyeing a 2 kg fleece required 90 litres of water. If the fleece were to be scoured or pre-mordanted a further 90 litres would be required for each procedure (Storey 1978, 67). The water quality is of importance. It has been asserted by Storey that water used in dyeing needs to be 'hard' for the dye and mordant to be most effective. Storey even suggests adding chalk to harden the water if necessary, (Storey 1978, 67). It has been asserted that the textile manufacturing

industry of other settlements, such as Bradford, took off due to the 'hard' nature of the local water, (James 1990), and so the mineral content of the water was a serious consideration. However, this assertion is misleading as hard water is only required for certain recipes. "It is best to use soft water for dyeing. Only a few dyeing recipes prescribe the use of hard water, *e.g.* Those for dyeing madder on iron mordant to obtain violet shades." (Schweppe 1986). Pompeii appears advantageously placed for dyeing as it is situated on a volcanic outcrop, so the water should have been soft (Arthur 1986; Peacock 1989). But the water was in fact hard as it was supplied from the plains via an aqueduct (Hodge 1981, 1992; Laurence 1994; DeHaan 1997). The presence of hard water means that despite the use of lead pipes, very little lead leached into the water that was delivered to the dye-workshops (Hopkins 2007). The water used during the reconstruction was also hard water, delivered by the mains water supply in central Bradford. The local housing is Victorian with residual lead pipes, so it was technically possible to provide an equivalent to that used in Pompeii, but as the lead did not leach into the water in Pompeii, this was deemed excessive.

Habitation in Bradford demonstrated the loss of a learned behaviour that was endemic in Britain throughout the 20th century and was likely to have been endemic in Pompeii. Those that had grown up with lead pipes let the water run before drinking it "to run off the stale [lead contaminated] water". The author was told by housemates at the beginning of the 21st century that this was "wasteful". The housemates, although aware of the lead piping, had lost the learned behaviour that made using lead pipes safe. The Romans were aware of the dangers of lead pipes, Vitruvius warns against it (Vitruvius 8.6.2), but beyond the lead workers no lead poisoning is recorded. It is probable that they too had learned behaviour that prevented poisoning, the most obvious of which was the use of hard, flowing water when the water supply used lead pipes.

The quantity and type of fuel to be used caused the greatest upheaval in the design and undertaking of the experiment. It would be disastrous to the dyeing process to exhaust the supply of fuel midway through using the replica, so it was necessary to determine how much fuel the apparatus would require. The fuel chosen was pine offcuts, not because it was felt that this was what was used, but because there was a steady supply from two local wood-yards and pine is of a known calorific value, 18,650 kJ/kg (Goodger 1980, 51). It was realised that in archaeology this was an unusual, possibly unanswerable, question, but in engineering it was a simple calculation relating to efficiency of the apparatus. The project for the first time began to depart from archaeology and theoretical classics and enter the realm of engineering.

Experiment One

Although kettles and braziers of differing sizes and shapes had been discovered in Pompeii, no lid had been found, which led to the conclusion that no lid had been used. It was speculated by both the archaeologists with dyeing experience and the engineers involved in the project that it was unlikely that the apparatus had been used without a lid: the archaeologists felt that the water loss through evaporation would be too great, the engineers felt that the apparatus would have been too inefficient. The first experiment was to discover whether a lid had been used. Without a lid the apparatus



Figure 8.3. Experiment One. Left: Without lid. Right: With lid.

lost 14 litres of water, a sufficient depth to cause the ruination of the fleece. It was calculated that a lid of 20 mm thick plywood would not only prevent a considerable amount of water evaporating but would also halve the heat lost through the top of the apparatus through evaporation (Hopkins *et al.* 2005). It was decided that such a lid should be used in future experiments (Figure 8.3). This was part of the original aim of the experiment: to determine if any parts of the apparatus were missing and to test the viability of the original design.

Theoretically charcoal should have been a better choice than pine as fuel as it has nearly double the calorific content, 34,750 kJ/kg, in comparison to pine's 18,650 kJ/kg (Goodger 1980, 51). However it was immediately dismissed as a fuel during the first experiments. There was insufficient airflow for complete combustion, a discovery made following practical attempts at its use and theoretical calculations. These two methods were tried independently to each other.

Experiment Two

Once the design had been shown to be viable and missing parts (the lid) added, it was possible to use the apparatus to mimic a dyeing cycle. The aim of Experiment Two was to determine the cycle-time and fuel requirement of dyeing with the apparatus. This included the time taken to heat the water and the time taken to simmer the dye liquor.

The recipe used stated that the water and dye should be heated to just below boiling,

the fleece should be added and simmered in the dye, again below boiling, then that the fleece should be allowed to rest in the dye as it cooled to allow the dye to become fast and prevent the wool from matting. The replica had a 130 litre kettle containing 90 litres of water. The water was heated to 95°C and a 2 kg fleece was added. The water took 1.5 hours to heat to 95°C, the recipe stated that the fleece should be simmered below boiling for 1.5 hours, then the replica took at least 8 hours to cool naturally. This was a replica of one of the smaller apparatus from Pompeii: it may be presumed that the 900 litres apparatus would have taken longer to cool. From this it was calculated that dyeing could only have taken place once a day as the length of time taken to cool would not have allowed a second cycle. It was concluded that the apparatus was emptied and cleaned in the morning, heated during the day and left to cool overnight. To heat the replica and keep the water simmering at c. 95°C took c. 126195 kJ of fuel which equated to 8 kg of pine.

Experiment Three

Following use of the replica the original apparatus in Pompeii were re-surveyed. This was the first survey undertaken with a practical understanding of the apparatus and its requirements. It is the most comprehensive survey to date. Each apparatus was assessed using Clarke's 'polythetic entities', a list of criteria that each must possess to be an apparatus (Hopkins 2007, 2008 after Clarke 1978). Each apparatus was also assessed ergonomically. All of the apparatus were demonstrated to have been of a viable design in their unconserved state, except for one identified by Moeller and discounted in this survey (Hopkins 2007; Hopkins 2011).

It was noted during the survey that there were two basic designs of apparatus: with or without a flue (Figure 8.4). The flue was an integral part of the apparatus that possessed one and did not appear to be an additional afterthought. The aim of the third experiment was to see what difference, if any, adding a flue to the apparatus would make. (The difficulty in amending a replica is discussed in Hopkins, forthcoming). The addition of the flue changed the reconstruction into a copy of VII xiv 17 vat 5. It was discovered that the quantity of fuel used and the time taken to heat and cool the replica were the same. However, the flame was far more controllable and less smoke was expelled from the front of the firebox. The flued apparatus were found in enclosed workshops and so it was suggested that the flues aided ventilation and complete combustion by helping to draw air through the firebox during heating.

Experiment Four

The temptation, when a problem arose, was always to reach for the volume of Vitruvius, conveniently to hand, rather than go to the site, often inconveniently distant, to look at the actual remains, much less, to cross the quad to that, psychologically at least, even more distant ultima Thule, the Faculty of Engineering.

A. Trevor-Hodge 1992.

As the study grew increasingly scientific it was realised that the questions that would really allow an understanding of the apparatus, what happened during its heating and how this would impact its output, could only be answered in Engineering. Thereafter the study relocated to the School of Engineering with a branch in Archaeology.

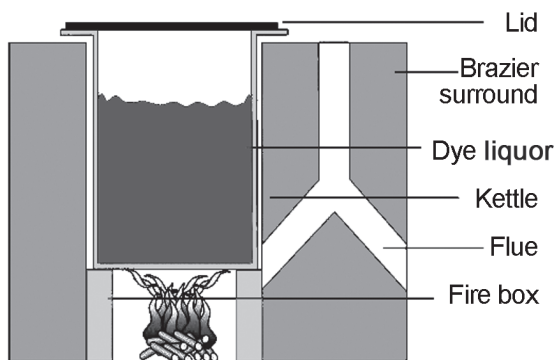


Figure 8.4. Flued apparatus. Above: Pompeii apparatus 5, property VII xiv 17. Top right: Replica apparatus. Right: Schematic of apparatus

To understand what occurred within an apparatus as it was heated it was necessary to record the temperatures of each part during the cycle. Experiment Four was a re-run of the dyeing cycle with six thermocouples in place to record the temperatures reached at varying points during the cycle. It was discovered that the temperature of the fire beneath the kettle was 600°C. Although the water would have acted as a heat-sink, drawing the heat away from the lead, there was disbelief that the original kettles had been constructed from lead as they should have had difficulty in supporting the weight. To find that the fire reached over 300°C above the melting temperature of lead added further intrigue.

That the kettle was constructed from lead had been noted in earlier studies but the importance of the choice of material had not been appreciated (Hopkins 2008). The concentric circles in the base of the vat and the distended kettle in the corner of property VII xiv 17 showed that the kettle had been subject to creep (Figure 8.5). As the material was lead, a metal known to creep just in hot sunshine (Greenfield 1972), it was suggested that creep could have played a far more important part in the failure and use of the apparatus than originally thought. It was therefore necessary to replicate the creep of the kettle to determine the speed of failure. Reynolds had been far more perceptive in his assertion that only the original materials should be used for a replica: he had stated that there could be qualities contained within an original material that



Figure 8.5. Concentric circles in the base of kettle in apparatus 5 and base of kettle in apparatus 6, property VII xiv 17, both showing evidence of creep.

while being unknown would still have an effect and that these should be allowed for. The stainless steel used had shared the same physical properties with lead except one: they do not creep in the same way. To replicate creep in a lead kettle it was necessary to use a lead kettle, something that was banned for health and safety reasons.

As one door closes another opens. Technological developments in the last thirty years meant that although it was not possible to use lead, it was now possible to replicate lead, to create a virtual simulation of the lead and its behaviour with the use of computer modelling. The apparatus could be recreated within a computer using Finite Element Analysis. This is the breaking down of the apparatus into parts, finite elements, each represented by an equation, then applying a force or temperature to one place and watching the reaction spread through the model. This had additional advantages: the environment surrounding the apparatus could be controlled, the apparatus design or materials could be altered and it was no longer necessary to construct all 40 apparatus to see how each reacted. Furthermore time could be speeded up or slowed so that twenty years of wear could pass in a day or the point at which the kettle failed could be studied minutely. The time taken for the original kettle to fail was unknown and it was not possible to wait indefinitely for a physical replica to fail.

Finite Element Analysis Results

The data required for the characteristics of lead to input into the FEA programme were defined during this project. This was done through use of the empirical creep strain-time data derived by Sahota and Riddington (2000). The use of FEA in testing the fatigue and failure of metals has been proven over decades: it is used to test aircraft wings. The

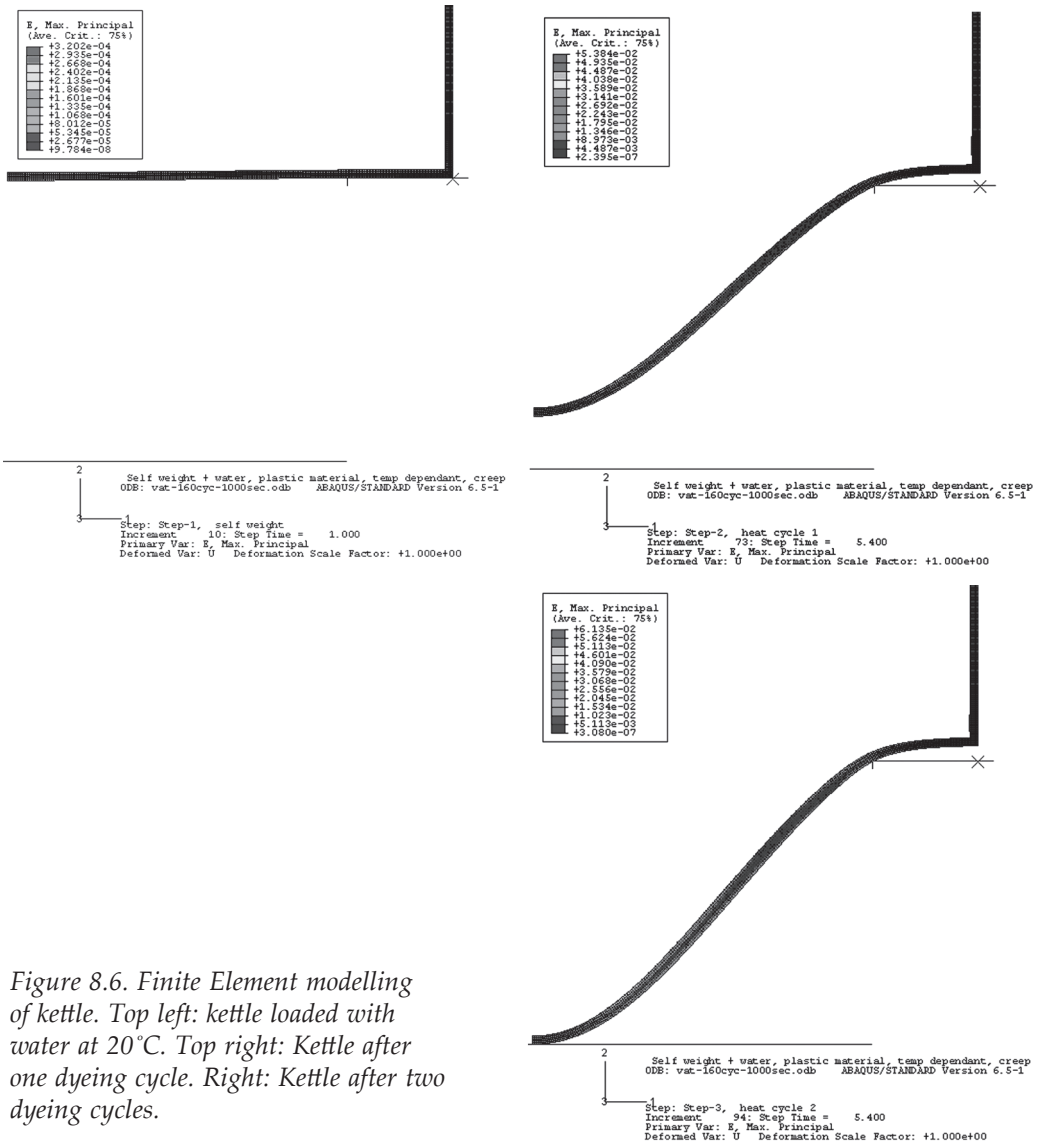


Figure 8.6. Finite Element modelling of kettle. Top left: kettle loaded with water at 20°C. Top right: Kettle after one dyeing cycle. Right: Kettle after two dyeing cycles.

results of this replication were unforeseen and groundbreaking. The lead did not fail. Loading with water and heating over the first hour caused the kettle to bow slightly and at the end of heating the lead bowed under the weight until it was just above the base of the firebox. By the end of the second heating the lead was resting on the base of the firebox (Figure 8.6). After six months, although the lead had thinned it had not sheared. It was concluded that breakage of the kettle was not a factor in the down-time of the process and that the kettle was amended after heating to allow its continued use.

Results

Many new findings came from this study. Between 48,972–53,106 fleeces could be dyed annually in Pompeii. By itself, this figure looks large, but the scale of output of an industry can only be appreciated if the population it supplied is also considered.

If the population of Pompeii was 12,000 (Storey 1997):

$$\frac{48,972}{12,000} = 4.1 \quad (4.081) \quad \frac{53,106}{12,000} = 4.4 \quad (4.4255)$$

If a Roman fleece weighted 2kg:

$$4.1 \times 2 = 8.2 \text{ kg} \quad 4.4 \times 2 = 8.8 \text{ kg}$$

The maximum output of the dyeing industry of Pompeii was between 8.1–8.8 kg of fleece per person. This may seem a significant quantity, but it is the equivalent in weight to a (large, possibly laundrette) washing machine load.

While it is true that not every piece of textile was dyed (*e.g.* Bender Jørgensen and Mannering 2001; Cardon 2001), the Romans did completely dye materials used in soft furnishings. When the quantity of wool required to make a blanket or cushions is considered, it is possible to see that the maximum output of an annual average of *c.* 8 kg of dyed textile per person would be quickly used up. The lead apparatus does not appear to fail despite repeated use. Further work would be required to calibrate the computer model and to see how the apparatus base could have been altered to allow continual re-use.

This study undertook the most comprehensive survey of the dyeing remains of Pompeii. Each of the apparatus and workshops were measured, recorded and assessed, individually and within context. The space, amenities and location of the workshops were assessed. It is now possible to examine further influences on the dyeing process and output.

Only two people were required to operate the dyeing apparatus, so of a population of 12,000 with six dyeing workshops, it is possible that only 12 were dyers. Following the start of the cycle only one was required (to monitor the apparatus). Both would need to be reasonably supple and fit, to lift, manoeuvre and cope with the heat, but only one would require dyeing skill. Who these dyers were is unknown as socially endemic ideas and economic restrictions have been lost. During the survey it was discovered that children used the apparatus: steps attached to many of them that were impractical for adults (Hopkins 2007). A skilled dyer would need to be bought with the skills or trained over years, so it is likely that these children were the dyers'. Slaves' freedom was often given with restrictions as a freedman would stay near his unfreed family and an unfettered skilled worker was a potential business rival, so often a freedman worked as foremen in their former workplace (after Mouritsen 2001). Dyeing was 'unclean', avoided by the upper classes, so freedmen were able to rise economically and socially in this role. Although a dyer may have been recognisable through occupational staining, if lead had accumulated through childhood it may go unrecognised as an increase in skill may lead to a diversification of role, from manual handler to overseer.

If the dyeing industry were operating at full capacity 14,588–14,903 litres of water

would have been required daily, 4,638,831–4,739,197 litres annually (Hopkins, in prep). If the dye required pre-mordanting then the figure rises from 4500 tonnes of water annually to 9000–10,000 tonnes. Following a survey of Pompeii it was concluded that as each dyeing workshop was located close to a supply of mains water acquiring this quantity would have been possible. It was also noted that each of the dyeing workshops had the ability to dispose of the water into a street where it could drain or be washed away by overflowing fountains. The practice of using public fountains to clean the streets may appear wasteful to modern eyes, but as the aqueduct was fed by a river it was not possible to stop its flow without resultant flooding and it provided an efficient means of keeping the streets clear (after Trevor Hodge 1992).

Numerous disciplines have been combined to answer the question of the dyeing capacity of Pompeii. Each has been shown to be relevant and vital. The use of some, such as ergonomics and the application of thermodynamic principles, were new to the question. The original mathematics to define the fuel requirement showed the difference between the expected and actual efficiency of the apparatus (Hopkins *et al.* 2005). The use or nature of application of others such as Finite Element Analysis were new to archaeology – FEA had only been used once before and that was to explore one quality of a single, portable artefact of one material (Kilikoglou and Vekinis 2002), whereas here it was used to explore multiple qualities of an industrial artefact of several materials, over time. A virtual model has advantages over a physical one: it is possible to slow and speed time, to change materials, to actually capture the moment at which a change in the materials takes place. This study has proved the use of each of these new techniques in the archaeological context. Furthermore, as the study was sequential it has increased accessibility, providing an illustrated example exploring each of these techniques in turn.

Conclusion

The challenges at the beginning of the study provided the rewards at the end. The study withheld greater scrutiny than it had been originally expected to be exposed to. In the end it was passed by three Grade 5 departments in two universities. Yet nothing is perfect and although the science provided a solid foundation, new questions have been posed by a modern professional historic dyer (Kania and Ringenberg, this volume). The study is ongoing, with further experiments expected in the near future.

For further background explanation and detail please refer to Hopkins 2007.

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References

- Arthur, P. (1986) Problems of the Urbanization of Pompeii: Excavations 1980–1981. *The Antiquities Journal*, 66, 29–44. Oxford University Press.
- Bender Jørgenson, L. and Mannering, U. (2001) Mons Claudianus: Investigating Roman textiles in the desert. In Walton Rogers, P., Bender Jørgensen, L. and Rast-Eicher A. (eds), *The Roman*

- Textile Industry and its Influence. A Birthday Tribute to John Peter Wild.* Oxbow Books, Oxford, 1–11.
- Brunello, F. (1973) *The Art of Dyeing in the history of Mankind*. Vicenza: Neri Pozza Editore.
- Callister, W.D. (2000) *Materials Science and Engineering: An Introduction*. John Wiley & Sons, Inc. New York.
- Capasso, L. (2001) *Palaeobiologia delle vittime dell'eruzione vesuviana del 79 d.c.* I Fuggiaschi di Ercolano. L'Erma di Bretschneider.
- Cardon, D. (2001) On the road to Berenike: a piece of tunic in damask weave from Didymoi. In Walton Rogers, P. Bender Jørgensen, L. Rast-Eicher, A. (eds), *The Roman Textile Industry and its Influence. A Birthday Tribute to John Peter Wild*. Oxbow Books, Oxford, 12–20.
- Ciarallo, A and De Carolis, E. (1999) *Pompeii – Life in a Roman Town*. Electra, Milan.
- Clarke, D. L. (1978) *Analytical Archaeology*. 2nd edn. Methuen & Co Ltd, London.
- Dalby, G. (1985) *Natural Dyes, Fast or Fugitive* Ashill Publications, Minehead, Britain.
- DeHaan, N. (1997) Water Use in Private Baths at Pompeii. The 98th Annual Meeting of the Archaeological Institute of America. *American Journal of Archaeology* 101, 355–356.
- Edmonds, J. pers. comms (1999) Chiltern Open Air Museum.
- Goodger, E. (1980) *Alternative Fuels*. Chemical Energy Resources. Macmillan Press Ltd.
- Greenfield, P. (1972) *Creep of Metals of high temperatures*. Mills and Boon.
- Grierson, S. (1986) *The Colour Cauldron*. Mill Brooks, Perth, Scotland.
- Grieve, M. (1992) *A Modern Herbal*. Mayers of Chatham, Kent
- Hodge, A.T. (1981) Vitruvius, Lead Pipes and Lead Poisoning. *American Journal of Archaeology* 85, 486–491
- Hodge, A Trevor. (1992) *Roman Aqueducts and Water Supply*. Duckworth, London.
- Hopkins, unpublished (Undertaken 1998–9) Laboratory investigation of the dyeing outcome of madder when used with differing mordants, temperatures and pH.
- Hopkins, H. J. (forthcoming) Experience versus Experiment: differing disciplines' definitions leading to the answering of 'unanswerable' questions, a case-study using Roman dyeing. In *Proceedings of the Third Conference of Experimental Archaeology*. Edinburgh University.
- Hopkins, H. J. (2007) *An investigation of the parameters that would influence the scale of the dyeing industry in Pompeii An application of experimental archaeology and computer simulation techniques to investigate the scale of manufacture of the dyeing industry and the factors that influence output*. PhD thesis, University of Bradford, 2007.
- Hopkins, H. J. (2008). Using experimental archaeology to answer the unanswerable: A case study using Roman dyeing. In Heeb, J. Paardekooper, R. (eds), *Experiencing Archaeology by Experiment*. Proceedings from the Second Conference of Experimental Archaeology. Oxbow Books, Oxford, 103–118.
- Hopkins, H. J. (2011) Using experimental archaeology to answer the 'unanswerable': A case study using Roman dyeing by Heather Hopkins. In Staubermann, K. (ed.), *Reconstructions: Recreating science and technology of the past*. NMS Enterprises Ltd – Publishing Ltd.
- Hopkins, H. Willimott, L, Janaway, R. Robinson, D. Seale. W. (2005) Understanding the economic influence of the dyeing industry in Pompeii through the application of experimental archaeology and thermodynamics. In R. C. Janaway and P. Wyeth (eds), *Scientific Analysis of Ancient and Historic Textiles, Informing Preservation, Display and interpretation*. Archetype Publications, London.
- James, D. (1990) *Bradford*. Ryburn Publishing, Halifax.
- Janaway and Robinson, unpublished (Undertaken 1994).
- Jongman, W. (1988) *The Economy and Society of Pompeii*. J. C. Gieben, Amsterdam.

- Kilikoglou, V and Vekinis, G. (2002) Failure prediction and function determination of archaeological pottery by finite element analysis. *Journal of Archaeological Science*, 2002, vol. 29, no 11, 1317–1325
- Lagercrantz, O. (1913) *Papyrus Graecus Holmiensis Recepte für Silbur, Steine und Purpur*.
- Laurence, R. (1994) *Roman Pompeii Space and Society*. Routledge, London.
- Mann, S. (1994) *A Review of the Evidence in Pompeii and Herculaneum on Textile Manufacture and Use*. Undergraduate Dissertation, University of Bradford, 2004.
- Mary Rose Trust. No author named. Consulted 15/11/2001 <http://www.maryrose.org/lcity/cook/galley1.htm>
- Mary Rose Trust. No author named. Consulted 15/11/2001. <http://www.maryrose.org/lcity/cook/galley3.htm>
- Moeller, W. (1976) *The wool trade of ancient Pompeii*. E. J. Brill, Leiden.
- Monaghan, M. D. (2001) *Coats of Many Colours: Dyeing and Dyeworks in Classical and Hellenistic Greece*. PhD Thesis. School of Archaeology and Ancient History, University of Leicester.
- Mouritsen, H. (2001) *Roman Freedmen and the Urban Economy: Pompeii in the First century AD. Pompei tra Sorrento e Sarno Bard*. Editore Roma
- Peacock, D. (1989) The Mills of Pompeii. *Antiquity* 63, 205–214.
- Pliny the Elder. *Natural History*, with an English translation by H. Rackham and others. Thirty seven books in ten volumes. Loeb Classical Library. Heinemann 1958–1962
- Ponting, K. (1980) *A Dictionary of dyes and dyeing*. Mills and Boon Ltd, London.
- Reynolds, P. (1999) The nature of experiment in archaeology. In A. F. Harding (ed.), *Experiment and Design: Archaeological Studies in Honour of John Coles*. Oxbow Books, Oxford, 156–162.
- Rosetti, G. (1548) *The Plictho of Gioanventura Rosetti: Instructions in the art of the dyers which teaches the dyeing of woollen cloths, linens, cottons, and silk by the great art as well as by the common*. MIT Press, London. English Translation 1969.
- Ryder, M. L. (1990) The Natural Pigmentation of Animal Textile Fibres. *Textile History* 21 (2), 135–48.
- Ryder and Stephenson, (1968) *Wool growth*. Academic Press, London.
- Sahota M. K. and Riddington J. R. (2000) Compressive Creep Properties of Lead Alloys. *Materials and Design* 21:3, 159–167.
- Schweppe, H. (1986) Identification of dyes in historic textile materials. In H. L. Needles and S. H. Zeronian (eds), *Historic textile and paper materials: Conservation and characterization*. Advances in Chemistry series 212. Washington, DC, American Chemical Society, 153–74.
- Storey, J. (1978). *Dyes and Fabrics*. Thames and Hudson, London.
- Storey, G. (1997). The Population of Ancient Rome. *Antiquity*. 71, 966–978.
- Vitruvius. *Ten Books on Architecture*. Translated by Morris Hicky Morgan. (1960). Dover Publications Ltd, New York.
- Wild, J. Peter. (1977). The Wool Trade of Ancient Pompeii. Review of Moeller, 1976. *Textile History*, vol. 8. Pasold Research Fund Ltd, Edington, Wilts., 180–181.

